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EDITOR'S FOREWORD.

In presenting the following papers, all relating to the manufacture of steel castings, the Society desires to encourage further friendly discussions of this most important problem which may lead to a better understanding between the Navy and our Steel Industry. Such an understanding is necessary in order that the ultimate result may be the ready availability of thoroughly sound steel castings, so necessary to the building of efficient treaty Naval vessels.

With relatively few exceptions, most of the castings used in Naval vessels are not particularly large and, when it is realized that the weight of steel castings in modern Naval construction approximates perhaps three and a half to four per cent of the total hull and machinery weights, it will be seen how large is the number and the variety of smaller castings used. Many of these castings are complex and in all of them, large and small, it is essential that

weight be reduced to the minimum necessary for strength requirements. It is safe to say that the number of steel castings used would be materially increased were it reasonably certain that sound castings could be assured.

The Navy is often criticized by producers for the severity of its requirements or specifications. Often the producers are not familiar with the Navy's method of purchase, which precludes the possibility of selecting its source of supply but which by law restricts it to a system based upon competitive bidding. Often, too, producers when first undertaking Navy work may not fully appreciate the severe conditions under which Naval machinery and equipment must reliably operate.

The Navy Department's program, as outlined in Captain Shane's paper, indicates that the Navy does not expect the impossible but that it does intend to know and hopes to take full advantage of the possibilities in the manufacture of steel castings. Its evident desire is to work with the Steel Industry of this country in mutual understanding and unanimity of purpose.

It would seem also from Captain Shane's paper that this same principle of "mutual understanding and unanimity of purpose" is applicable and actually exists within the plants of all successful steel companies. The designers, draftsmen, patternmakers, molders all must be guided, supervised and directed, and the work of all brought together in harmony through a coordinating staff whose knowledge and ability are sufficiently broad to understand thoroughly and to direct the whole process for the purpose of producing a satisfactory result.

The American Society of Naval Engineers, of course, can take no part in the discussions; nor is it in any way responsible for the opinions or statements of the authors. It does urge those interested to submit further discussions relating to the subject of steel castings in order that the greatest benefit may be derived by all concerned.

A BIRD'S EYE VIEW OF THE STEEL CASTING SITUATION IN EUROPE.

By Captain Louis Shane, U.S.N., Member.

For many years the steel casting situation in the Navy has been the cause of concern to all Naval officers who have had experience with steel castings either as users or as inspectors at private steel foundries. It is safe to say there are few important steel castings in many of our Naval ships that have not been patched by welding.

In itself, welding is all right. The difficulty with welding is that its necessity is indicative of a condition which may exist, and usually does, throughout the casting. Many common defects, such as porosity, blow holes, hot tears, cold shuts, shrinkage cracks, interior cavities, pipes, et cetera, may exist, unknown, because there has been no machining operation to expose them.

The situation became increasingly acute until in 1931 the stern posts of several Scout Cruisers developed such defects that it was necessary to replace them. This brought more forcibly than ever before to the attention of the Navy Department the fact that the Navy itself must take a more active part in finding a satisfactory solution of the steel casting problems. As a first step a comprehensive study of the industry both here and abroad was decided upon. Being familiar to some extent with the situation in the United States, I was directed to go to Europe to visit the foundries there, many of which seemed to enjoy excellent reputations for turning out sound castings.

Thirty-eight steel foundries in France, Germany, Poland, Czecho-Slovakia, Switzerland, Italy, Holland, Belgium, England and Scotland were visited. There seemed to be about as many differences in technique as there were foundries. I visited one foundry and found they made excellent steel castings. I examined and recorded the technique and became thoroughly satisfied that I had the answer to all foundry troubles. Then I visited another foundry where the technique seemed entirely different

from the previous one, yet it produced equally good castings. Then I didn't know where I stood, until after visiting many other foundries, I began to realize that in the successful foundries the methods were basically similar. There were differences in detail but not in fundamentals. All of them were operated on engineering lines. Nothing was done in a haphazard manner. Where natural advantages did not exist other methods were substituted to supply the deficiencies.

In Italy, for instance, there are neither coal nor ores. Both have to be imported. Neither do they have a good natural sand. They do have, however, large hydro-electric power plants and electric current is very cheap, so they naturally use electric furnaces. Ores are imported, and they use "Chamotte" in lieu of natural sand.

At Pilzen, Czecho-Slovakia, they lack the fine natural sands of Northern France and Belgium, so they make up a series of twenty-five different blends of sand, using as much local sand as possible in various combinations with imported sands, depending on the castings to be made. Here as at other plants, for important castings they use "Chamotte," which will be described later.

I found the Italian foundries very up to date. At a typical Italian plant in Turin there are 4 arc furnaces of 10 tons capacity each. The Plant is very modern. All sand is imported from France and Belgium and, because of the high transportation costs, elaborate sand reclaiming and control apparatus has been installed. Many Diesel bedplates and housings were being made and no welding was necessary.

As a matter of incidental interest, at one plant visited where four units of 50,000 Kw. of a 400,000 Kw. plant were installed, they had considerable trouble with erosion of their hydraulic turbine rotors. They got only 8000 hours service from these. Finally, they substituted corrosion resisting steel castings and they now get an average of 33,000 hours.

Great effort is made to get fluidity conditions right. Most foundries prefer the higher carbon steels because of the better physical properties, but more particularly because fluidity is obtained at lower temperatures. At a large foundry in Milan, Italy, a spiral mold is prepared with spirals about ⅜ of an inch thick.

A sample of the heat is poured in till the metal sets in the mold. It is then shaken out, and the length of the casting is a measure of the fluidity of the metal. In the mold are certain marks and the number of these marks passed determines the actual fluidity. This method is used instead of depending upon temperature, because notwithstanding every effort made to get conditions uniform for all heats, unknown differences do creep in, and fluidity is not necessarily always obtained at the same temperatures.

A criticism of American foundry practice often heard abroad is that American foundrymen hurry the process too much. Making good steel is much like making good broth by a competent chef. He has to take time to let the ingredients blend properly. So with steel.

Another statement made is that the temperature of steel should never be higher than that for the required fluidity. Heating to an unnecessarily high temperature and then permitting to cool is not good practice, because the metal has lost something in the extra heating that it does not recover on cooling. Of course, for low carbon steel and for very thin section castings higher temperatures are necessary, but this becomes merely a necessary evil.

Near Lille, in northern France, are two steel foundries, the technique of one being quite at variance with that of the other. At one no chills whatever are employed. But they use tremendous risers. On some of their castings the risers weigh from three to four times as much as the casting proper. In answer to a question as to why such large risers were used, the manager replied that risers were much cheaper than replaced castings. He did not believe in the use of chills, particularly internal chills, because he did not believe the chills fused completely. On the contrary, at the other foundry, the risers were quite modest, but great resort was had to internal chills of the horseshoe nail variety. Wherever two sections joined of different thicknesses, the heavier section was thick with horseshoe nails. I saw a mold of the turbine casing for a Destroyer which looked like a porcupine because of the number of horseshoe nails used. (Fig. 1.)

There was no doubt in the management's mind that these horseshoe nails fused. Often castings were cut up to satisfy themselves on this point, and the results always justified their faith in the use of this type of chill.

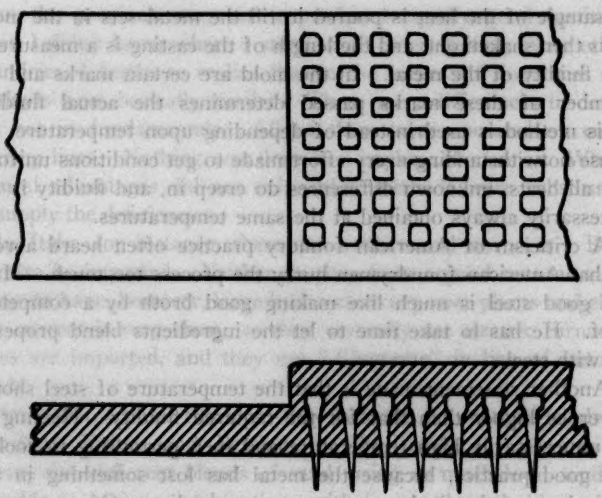

Fig 1.

The endeavor is, of course, to get a uniform rate of cooling throughout the casting. In the use of risers, the average weight throughout Europe is about 80 per cent of the weight of the casting. In all cases, no matter what the size of the riser, the riser section is always greater than the section it is feeding, the intention being for the riser to feed the casting and not the reverse.

Cores are almost invariably hollow and filled with coke or cinders. The walls are quite thin, in fact at times they break down when the casting is poured. Nevertheless, they do not thicken the walls of the cores. This is, of course, to facilitate the collapse of the cores during the shrinking of the casting.

With few exceptions the European foundries make excellent castings. This is due to several causes, the greatest of which is, in my opinion, that practically every foundry in Europe is scientifically operated by expert engineers rather than by Old Man

Noah. Engineers control the whole operation in Europe, and have done so for some years. It is general practice for the European foundries rather than the customer to make all patterns for castings. This has a two-fold advantage. First, the foundries being specialists have better knowledge of how patterns should be made. Second, all pattern alibis are eliminated. A third advantage might be the discovery that the particular design could not be manufactured. The matter could then be taken up with the customer before the pattern is made with a view to making necessary alterations in the design to permit the manufacturing of a sound casting.

The foundry drawing room goes over the plans and in consultation with various experts they determine the location and size of the risers, location and character of the chills, if any, and the riser pattern then becomes part of the main pattern.

The melting of the metal is under the direct supervision of the metallurgist from the time the furnace is charged until it is tapped. The heat treatment is also under his supervision.

FEATURES OF EUROPEAN METHODS.

The following are some of the more noteworthy features of European method of producing steel castings:

Equipment.

The equipment is practically the same as found in the steel foundries in the United States.

Melting Furnaces.

Melting furnaces are of different types, such as:

Converters { Tropenas, Stock, Bessemer
Open hearth, basic and acid.
Arc furnaces, basic and acid.
High frequency induction furnaces.
Crucible furnaces.

On the Continent, the converter is practically out of the picture. The French government does not permit any converter steel to be furnished and except for unimportant castings, converters are

not used even for commercial work. In many of the steel foundries in Europe converters may be found, but as secondary equipment. The general opinion is that electric steel is the best, followed by crucible and open-hearth. In only one foundry visited in Continental Europe, in Charleroi, Belgium, was converter steel made exclusively. The capacity was small and small castings only were made. The pig iron was imported from England. There were two Bessemer converters of 2 tons capacity each. In all other Continental foundries visited the converters, where used, were for the poorest grades of steel only. Most of the converters were the Tropenas type, as side blast was preferred to bottom blast. In England the electric furnace is gaining ground, and now perhaps half the equipment is electric. However, many foundries in England still prefer the converter, and here also the Tropenas is usually preferred to the Bessemer. In some foundries the Stock furnace is used. This combines the functions of the Cupola and Tropenas furnace. Oil is used at the bottom to melt the charge and when this is done, the oil is shut off and side blast put on. From here the procedure is as in the Tropenas process.

At Letchworth, England, the Tropenas process has been modified in accordance with a paper presented by Mr. C. H. Herty, Mr. C. F. Christopher and Mr. M. W. Lightner at the Spring meeting of the American Foundrymen's Association, May 2-5, 1932. This equipment is interesting both from the Cupola viewpoint as well as the Tropenas furnace.

The Cupola is the conventional iron cupola with some modification. The tuyeres in the air belt are restricted and 2½-inch pipes from the belt are led to enter the cupola at several points from 2½ to 10 feet above the belt in pairs, each pair being 180 degrees apart. The object of this is to burn the fuel to CO abreast the air belt. Then the metal melting higher up drops into a reducing atmosphere and this results in a purer iron. The air pressure is 10 ounces with 250,000 cubic feet of air for 6-ton capacity.

From the cupola the iron is tapped into a neutral (ganister and crushed graphite) lined ladle in the bottom of which 1 per cent by weight of soda ash has been placed. Ore much higher in sulphur than usual was used in this acid process. By the use of soda ash the sulphur content was reduced 50 per cent. In the ladle the

sulphur combines with soda ash to form a slag lighter than the metal and floats to the top. This is accompanied by violent bubbling. When the bubbling is completed the ladle is skimmed off with a wooden bladed skimmer, then discharged into the Tropenas converter, where the remainder of the process is conventional with the exception of the blast pressure and silicon percentage which are 1 pound and 1 per cent, while the conventional is 6 pounds and 3 per cent.

Neutral lining of the ladle was resorted to so that many heats can be poured from it without relining. With the ordinary acid lining, when using soda ash to reduce the sulphur content, the lining lasts for very few heats. When neutral lining is used, 200 heats can be poured before relining is necessary.

In this process ores containing from .09 to .12 per cent sulphur can be used and the final analysis of the metal shows only from .03 to .05 per cent.

The physical properties of the .35 Carbon steel produced in this manner are excellent, a sample heat being as follows:

Tensile Strength	38 tons
Yield Point	21 tons
Elongation	28 per cent in 2 inches
Reduction in Area	39 per cent
Bend Test	180 degrees with 1-inch bar

Fluidity of steel is obtained at a lower temperature in a converter than in open hearth or electric furnaces.

As stated above the general European opinion is that open hearth and electric steels are much superior to converter steel. In foundries with large capacities the principal furnaces are open hearth. However, practically all had electric furnaces in addition. Open hearth furnaces can be made in large capacities, and some plants have them up to 65 tons.

In Switzerland and Italy there are fewer open hearth furnaces due to the greater cost of operation. Neither Switzerland nor Italy has any coal, consequently it has to be imported. As both these countries have large hydro-electric plants and current is very cheap, they use principally electric furnaces. Each important foundry, however, has at least one open hearth furnace for use in case power costs become excessive.

The basic process is the one usually employed because of the lack of pig low in sulphur and phosphorus. In large plants there may be one acid lined furnace to produce special steel.

Practically every foundry on the continent operates at least one electric arc furnace. The industry is so thoroughly convinced that electric steel is superior to any other that they all have at least one such furnace to get specially fine steel. At one plant at Seraing near Liege, Belgium, they state that frequently when they fail with the Siemens-Martin furnace, they have no difficulty with the arc furnace.

As previously stated, Switzerland and Italy on account of the cheap electric current and high cost of coal produce almost exclusively electric steel. Most of this is basic steel, though as in the case of open hearth plants, an occasional acid lined electric furnace is used for special purposes. Some arc furnaces have a capacity in excess of 25 tons. The basic arc furnaces are operated almost exactly as are the open hearth furnaces. The charge is melted and purified and at the proper time the modifiers are added to produce the type of steel required. After tapping of the furnace the treatment of the metal in the ladle, whether produced by the open hearth or arc furnace, is the same.

The following is a typical heat at a Switzerland foundry:

Steel turnings	1100 kilograms.
Steel scrap	600 kilograms.
Risers	1500 kilograms.
*Pig	30 kilograms.
FeMn (76 per cent)	12 kilograms.
FeSi (45 per cent)	7 kilograms.
Pig	60 kilograms.
Aluminum Silicate	3 kilograms.
	3312 kilograms (3¼ tons).

It will be noted that at this plant instead of introducing the aluminum into the ladle after tapping the aluminum is introduced

* This pig is introduced only if furnace has been permitted to cool. Otherwise the increased time necessary to heat up would reduce the carbon too much and this pig is used to make up for the loss in carbon. If the furnace is hot this pig is not used.

into the bath as an aluminum silicon alloy. The composition of this alloy is 43 per cent aluminum, and 42 per cent silicon.

Ladles are often provided with vents through the lining to make sure no volatile matter from the linings escape through the metal in the ladle. For large castings bottom pour type ladles are used. I saw no tea-pot type ladles.

In many plants in addition to the open hearth and arc furnaces, there are employed high frequency furnaces (Ajax type). Most of these are of small capacity and as a rule are employed only for special alloy steels.

At St. Etienne, France, however, these are used exclusively. Originally this plant was exclusively a crucible steel plant, and engaged in producing only the finest of steel alloys. With the perfection of the high frequency induction furnace, this plant changed over completely from crucibles to induction furnaces, and now produces exactly the same quality of steel as previously produced in the crucibles. Due to several causes, among which is the fact that melting in the induction furnace is much faster than in the crucible (in fact, faster than any other method of melting) the production costs are considerably less than with crucibles, although still somewhat higher than with the arc furnace. Some of the excessive cost over the arc furnace is explained by the royalties that have to be paid on the high frequency furnace.

In any case, one of the most important steel plants in France uses the high frequency induction furnace exclusively. Of these they have several, the largest two being of 2000 kilograms and 1800 kilograms, respectively. The larger furnaces operate on a frequency of 1000 cycles, the smaller furnaces on 2000 cycles.

Crucible furnaces are used in some plants, but almost exclusively for special alloys, and not in large capacities. This is the most expensive method of producing steel, consequently, except for special alloys, they prefer as a rule the electric arc or open hearth furnace.

Furnace temperatures, as reported to me, varied from 1450 degrees C. to 1800 degrees C. This depended considerably on the carbon content of the steel, though there was considerable variation in the reported temperatures of pouring steel of the same carbon content. It is possible this may depend on the man taking the pyrometer readings.

ANNEALING FURNACES.

Every foundry in Europe has a large battery of annealing or heat treating furnaces. Not one steel casting ever leaves the foundry without at least one annealing. The annealing process is similar all over Europe. More attention is paid to the rate of cooling than to the rate of heating.

The temperature of annealing varies from 840 degrees C. to 950 degrees C. for carbon steel, depending on the carbon content (the temperature being lower with higher carbon), and 1000 degrees C. to 1050 degrees C. for corrosion resisting steel. After the required temperature is reached the casting is permitted to soak about 12 hours then permitted to cool slowly, the time depending on the weight and design of the casting and its complexity.

One plant normalized first, that is, heated the casting to 925 degrees C. in a car furnace, soaked it for the appropriate time, then withdrew the car to permit the casting to cool in still air until black. Later it was again put into the furnace, the temperature raised to 700 degrees C. and soaked, and permitted to cool slowly.

No definite rule can be given as to how long a casting should cool. It depends on the size and shape of the casting, and only experience can govern the determination of the time.

In the case of corrosion resisting steel and manganese steel, the annealing operation consists of raising to the right temperature, and then plunging the casting into a bath of water at room temperature.

The furnaces are of two types, floor and pit. In the floor types there are cars on which are loaded the castings to be annealed and introduced into the furnace on tracks. Sliding doors close the entrance. The pit furnaces have sectional crowned roofs which are removed and replaced by cranes. The castings are also introduced with the crane.

The furnaces are usually either coke or gas fired. In one case the furnace was oil fired. Recording pyrometers are usually part of the equipment, and the temperatures are carefully controlled, particularly in cooling.

DRYING OVENS.

There are two types of mold ovens, the fixed and the portable. The smaller molds are dried in the fixed ovens, the larger ones by portable ones. All are fired either by coke or gas. The usual drying temperatures for molds are between 400 degrees and 500 degrees C. The floor molds are dried with portable ovens. These are placed over the molds. Air, either by blower or by compressed air hose, is forced or drawn through the oven and circulated through the mold until it is well dried. The method seems crude, but is effective. However, they endeavor to pour the castings as soon as possible after assembly of the molds, as the latter are hygroscopic and absorb a surprising amount of moisture if the pouring of the castings is delayed. At a plant in Scotland, due to the depression, there was not sufficient work to call for daily operation of the furnace. They made up the molds and when a sufficient number were ready to justify operation of the furnace, a heat was run. However, due to their hygroscopic quality there were many losses among the molds first prepared, far more than had occurred when heats were run daily.

Core ovens are somewhat differently operated. In the most progressive plants the temperatures of core ovens were carefully regulated by the use of recording pyrometers. The temperature of core ovens varied with the type of core. With ordinary sand cores the temperatures would be rather high, from 350—400 degrees C. With ordinary oil sand (silica) cores the temperature was about 250—300 degrees C., and with cores where silica sand was used with dextrin and linseed oil as binder, the temperature varied from 180 degrees to 200 degrees C.

In the case of silica sand cores (oil) the temperature had to be watched carefully so that it should not be high enough to burn out the binder which would result in breaking down the core during the pouring of the casting.

SAND.

The sand control equipment is very much like that found in United States foundries. In fact a large part of the equipment in Continental European countries was obtained in the United States. Even the sand testing equipment is of United States manufacture.

The question of sand is one of the most important in all foundries of Europe. In Northern France and in Belgium the problem of sand is very simple. It is almost universally agreed that the best foundry sand in the world is obtained in Northern France and Belgium. This sand is of reddish yellow color, and feels somewhat sticky. It seems to have exactly the right amount and quality of binder. Where the transportation costs are not excessive this sand is used. The qualities of this sand are such that in many foundries no other sands are used for any purpose, this sand being equally good for cores and molds. Where the transportation costs are excessive, however, it has been necessary to develop synthetic sands, and of these there are many. At some of the foundries sand pockets exist, so that there are no transportation costs. One Czecho-Slovakian foundry has 25 different blends, which is the largest number in any foundry visited. These blends are produced in many ways, the endeavor being to use as much local sand as possible in combination with known foreign sands.

"Chamotte" is used in most foundries of Europe in lieu of natural molding sand. "Chamotte" consists of clay roasted at a high temperature making the resultant very refractory. This clay is introduced into roasting ovens in 9-inch cubes, roasted at above 1500 degrees C., when it breaks into pieces about the size of egg coal. It is then ground to the required fineness. For molding, this ground "Chamotte" is mixed with green clay binder in the proportion of 6 "Chamotte" and 1 green clay. With the proper amount of water added this makes an excellent molding material. The general impression is that there is scarcely any sand trouble that "Chamotte" will not cure. The analysis of "Chamotte" is as follows:

	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO
"Chamotte" Krupp.....	56.46	37.50	2.5	1.8	.5	.8
"Chamotte" Echantillon	63.50	31.75	2.15	1.17	.0	1.0

"Chamotte" is used when ground fine as a mold wash. However, graphite is used more often for this. Castings made in "Chamotte" molds are said to machine more readily than those made in other sands.

For cores either "Chamotte," Belgian sand or silica sand is used, depending on the location of the foundry and the purpose for which the core is used.

At one plant in France, the molding sand is prepared as follows:

1650 kilograms mixture of 2 parts "Chamotte" and 1 part 25 per cent silica sand,
30 kilograms coal tar
80 liters water.

The above is thoroughly crushed and mixed in a mill and used as facing sand in molds. For backing sand they use old sand with 10 per cent clay as binder. Before the introduction of the high frequency electric furnaces one plant used their worn out crucibles for sand. These were crushed and used just as "Chamotte" is now used to make their molding material.

In Northern France and Belgium the ordinary sand is used for cores as well as molds, except in special cases, such as for jackets, etc., where core wire would be difficult to remove, in which case oil sand cores may be used. Oil sand cores are very much like those used in the United States foundries, with wax tapers for vents. However, frequently in addition to linseed oil dextrin is used, in equal quantities, that is from 1½ to 2 per cent of each. The object of the dextrin is to facilitate skin drying which permits of the ready patching of cores. Also, when dextrin is used with linseed oil the core oven temperatures are reduced from 250–300 degrees C. to 180–200 degrees C., and there is not the same danger of burning out too much of the binder during drying.

Because it is so difficult to vent some jacketed molds one German foundry has developed a special mixture that does not give off as much gas as ordinary oil sands. This mixture is composed of fine silica sand and powdered brown lignite with a binder of black oil, the composition of which I was unable to get.

When the cores are made of ordinary sand or "Chamotte," frequently the binders are either glyso, or sulfitlauge, a by-product of the paper mill—that is, the bisulphite process of paper manufacture from wood pulp, which is as follows:

Burn sulphur to form SO_2 gas. Pass through "milk of lime" for absorption, forming calcium bisulphide. After cooking with steam the wood is washed with pure water. The resulting liquid is sulfitlauge. This product is also used in tanning and as a binder for coal dust briquets.

The percentage of sulfitlauge usually is about 4.

Glyso is a prepared binder much used in England. This has replaced sulfitlauge. In one British plant the synthetic sand is made up by mixing silica sand with a Yorkshire sand. The Yorkshire sand is a natural mixture of 50 per cent clay and 50 per cent silica sand. In making up the molding sand the proportions are 9 parts Yorkshire sand to 36 parts of silica sand, which again is a mixture of ⅓ new and ⅔ reclaimed sand. The old sand reclaimed is separated from dust by mechanical separators, which they find to be superior to the blower type of separator. When using sulfitlauge as binder they use 6 per cent, somewhat higher than on the Continent where only 4 per cent is used. They now use glyso in the proportion of 1 quart glyso to 5 bushels of sand. This is thoroughly mixed. In making the sand mixture, the silica sand is dry and the Yorkshire sand is moist. This with the glyso is all the binder or moisture used. The cores are made up of a finer silica sand and glyso.

In all cases where cores are large enough the facing only is of sand prepared as above. The middle of all cores consists of either coke or cinders. This is to facilitate the collapsing of the cores when the casting shrinks. The molds proper are so constructed that only from ¾ of an inch to 1¼ inches of the facing is of new sand. The backing is of old reclaimed sand, and effort is made to ram the sand much more loosely in the middle than against the pattern and flask. In other words, the molds are so constructed as to collapse when the casting shrinks along certain dimensions, such as between flanges.

CHILLS AND RISERS.

The procedure with respect to chills varies. Some foundries never use chills of any kind, depending entirely on properly placed risers of ample size. It is generally agreed that a properly placed

riser is better than a chill, but some foundries state it is not possible to place risers at all points where shrinkage takes place, therefore chills must be used at these points. Other foundries use many chills, both internal and surface. Where many chills are used the risers are very modest, while where the chills are more sparingly used the risers are larger. Where several sections cross, internal chills of the horseshoe nail type are usually used in order to insure the setting of that part of the casting first. Flange webs or brackets are also freely used. Occasionally, the risers vary in size with the same kind of mold. The molds poured first have small risers, and those poured last have larger ones to compensate for the loss of heat from the metal in the ladle.

At a German foundry, in making a cylinder casting like the accompanying sketch, the riser went through the cylinder to the boss at the bottom. The riser, it will be noticed, tapered from top to bottom. In addition the cylinder was cast eccentric, the larger section being on the top. This was to help feed the bottom or thinner part. The cylinder was machined concentric in the machine shop. This merely illustrates the care taken to insure the proper feeding of castings. The riser was cut off with the oxy-acetyline torch.

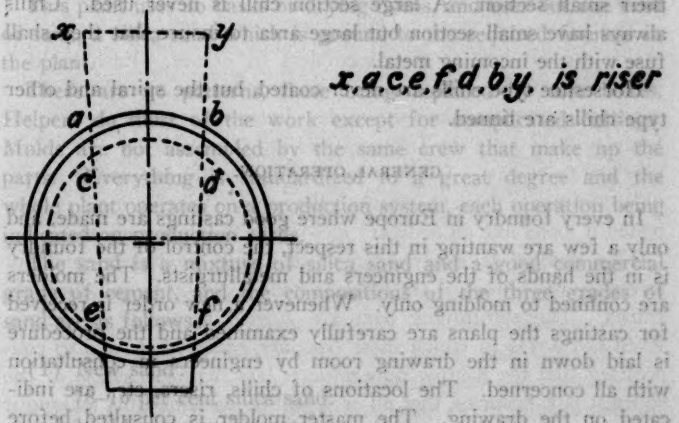

Fig 2.

At the same plant there were a number of Diesel engine bedplates with four bearings and five crankshafts. There were twenty risers on this casting, four at each bearing, two on the outer edge abreast the bearings, and two on the inner edge of the bearings. All these castings were without a flaw.

One small casting weighing perhaps 60 pounds, at Remscheid had seventeen risers. It was an important casting, and there was a riser at each part where there was likely to be a draw.

Some plants employ blind risers in addition to the regular risers. I have seen risers on castings in three planes. The blind risers have half inch vents at the top.

At Feignies, France, immediately after pouring a large casting with two large risers, the moment the pouring was completed and the ladle withdrawn, two barrels of water were upset on the risers. I expressed surprise that they did not permit the risers to feed longer and was informed that what feeding there was had already taken place. It takes only seconds for castings to set. This has been confirmed at the Naval Research Laboratory where tests to determine the time it takes a casting to set have been made.

One noticeable thing with regard to the use of internal chills is their small section. A large section chill is never used. Chills always have small section but large area to insure that they shall fuse with the incoming metal.

Horseshoe type chills are never coated, but the spiral and other type chills are tinned.

GENERAL OPERATION.

In every foundry in Europe where good castings are made, and only a few are wanting in this respect, the control of the foundry is in the hands of the engineers and metallurgists. The molders are confined to molding only. Whenever a new order is received for castings the plans are carefully examined and the procedure is laid down in the drawing room by engineers in consultation with all concerned. The locations of chills, risers, etc., are indicated on the drawing. The master molder is consulted before definite action is taken, but when the decision is made, the pro-

cedure is definitely set by the engineers. If the order is a large one, the first casting made is cut up and examined to determine if variation of procedure is necessary before putting the work into production. The furnaces are operated under the supervision of the metallurgist from the time they are charged until they are tapped. Record is taken of the sequence of operations for each heat, such as when charged, time of melting, modifying, etc. Temperatures are taken by optical pyrometers, and as these operate by comparison, the same man is used for that purpose at all times. He stands in the same spot, uses the same apparatus, etc., so as to eliminate as much as possible changes in personal errors. The heats are never hurried, as the general opinion obtains in European foundries that hurrying a heat is likely to spoil it. Neither do they try to get too many heats out of a furnace before relining.

In other words, the production of steel in most foundries is under expert supervision at all times.

One plant in the French Alps merits special mention in that it has distinctly a different method of making molds, though the furnace operation is practically like that in all other plants. Here, too, the engineer supervises the whole procedure which is patented.

This plant uses no flasks or drying ovens, and uses but one kind of sand, a silica sand which is ground to the required fineness in the plant.

There are no patterns, these being replaced by core boxes. Helpers do most of the work except for complicated castings. Molds are not assembled by the same crew that make up the parts. Everything is standardized to a great degree and the whole plant operates on a production system, each operation being indicated on production cards.

The sand is a mixture of silica sand and a good commercial grade of cement, and the compositions of the three grades of sand are as follows:

(1) New sand:

78–76 per cent silica sand.

12–14 per cent cement.

Remainder water.

(2) Part new and part old sand:
Mixture of 60 per cent new and 40 per cent old.
78–80 per cent of above mixture.
12–10 per cent cement.
Remainder water.

(3) All old sand:
Old sand 80–82 per cent.
Cement, 10–8 per cent.
Remainder water.

Helpers make most of the molds in core boxes. When the boxes are removed the molds are on a follow board. Cranes take the molds to drying racks where the molds dry in the air in 24 to 48 hours. After 8 hours the molds can be handled freely. Half inch rods of varying lengths are used to strengthen the molds. Thus it is recognized that these molds are made up of a poor type of reinforced concrete. These molds can be sawed, trimmed, nails can be driven into them, and in fact they can be handled roughly without harm.

The whole foundry is laid out for mass production. All parts are labeled and when a certain number of like pieces have been made they are put into the drying racks.

The afternoon shift assembles the molds. The parts for the molds are brought to the assemblers by cranes. Each mold is tested for permeability, and when completely assembled, hand operated conveyers take them aside. Later cranes take them to the foundry floor near the furnaces and lay them side by side where they are to be cast. Large iron weights, mostly railroad iron, are placed on top to prevent lifting of the copes. When a mold is completed it looks like an ordinary mold with the flask removed.

This method is easily adapted to single production and for sweeping up. Most of the work is done partially by molding machines. The reinforcing bars are stowed according to length. Even the boxes in which these bars are gathered up are so constructed that the narrow dimension is less than the length of the shortest bar, ensuring that all bars will be parallel, thus making it easy to remove from the conveyer.

No provision is made for venting except in the real cores, as this sand is so permeable that it is unnecessary. It is not possible

to over-ram this sand. If the ramming is too hard, the sand merely flows out, consequently molds are always uniform.

Risers and gates are of standard sizes, and many of the different sizes are always made up. The production card indicates which are to be used.

Many advantages are claimed for this process of molding, among them the following:

1. No flasks necessary.
2. No core ovens necessary.
3. One kind of sand only.
4. Greater uniformity.
5. Helpers do most of the work.
6. Smaller capital investment.
7. Lower cost of production.

There is some difference of opinion regarding the last claim, as some British foundries state that due to the high license fees demanded, they could not produce castings as cheaply by this method as by the conventional method.

In the use of sand, new sand is used for particularly important pieces and for facing all steel castings. For grey iron they use mixture No. 2 (part new and part old) for facing. In both cases the backing sand is old sand. The facing is ¾ of an inch thick. In large cores the filling is coke. This sand is also used for non-ferrous metals.

No wash is used on steel molds, but a graphite wash is used on iron molds. Castings are easily cleaned, the sand falling off readily. Castings are sand blasted, and then annealed. Corrosion resisting steel, after annealing, is pickled as follows:

The castings are put into a 20 per cent solution of sulphuric acid at a temperature of 60 degrees C., then transferred into a 25 per cent solution of nitric acid at room temperature. By experience they know what color the castings should assume (a dull silver color) and the castings remain in the solution until this color is obtained. The time in each bath is approximately 20 minutes. The castings are then washed in fresh water.

This method of pickling corrosion resisting steel castings also obtains at one other foundry in France. No other foundries visited pickled corrosion resisting steel castings.

Pickling, with the exception of corrosion resisting steel castings is seldom employed on the Continent. And only a few foundries employ pickling for corrosion resisting steel. This rather confirms my own opinion that pickling of ordinary castings is highly undesirable. It will cause more defects than it will show up. Defects caused by pickling are progressive. Pickling has ruined many a good casting. In England, however, the British Admiralty require the pickling of all castings that are to be used with steam. This is also the practice of the Parsons Marine Turbine Co., of Newcastle-on-Tyne, England. I was informed that pickling was required because of the erosion of turbine blades from sand in castings, and they wanted to make sure the sand was all removed. My opinion is that the British Navy has excessive erosion of turbine blades because of pickling castings, because the corrosive properties being progressive it is difficult to determine when they stop. In the meantime, the products of corrosion enter the turbines with the steam and erode the blades.

DEOXIDIZERS.

The procedure with regard to the introduction of the deoxidizers varied somewhat. As a rule the ferro-silicon and ferro-manganese were introduced into the bath about 20 minutes before tapping the furnace. Usually about 500 grams of aluminum per ton were introduced into the ladle. However, one plant introduced the manganese into the original charge in the form of 60 per cent manganese ore, the ferro-silicon and aluminum being introduced in the usual manner. Some plants introduce the ferro-manganese into the ladle and others introduce the ferro-silicon into the ladle. Occasionally no aluminum at all is used, and on occasion ferro titanium is used in conjunction with aluminum in the ladle, about 200 grams per ton.

The method of introducing the aluminum also varies. In most plants the aluminum (usually 500 grams per ton) is introduced into the ladle after tapping. However, some plants which produces some of the finest looking castings made in Europe, intro-

duce the aluminum into the metal stream while pouring the casting. A man who knows the approximate weight of the casting puts two small pieces into the gate, then as the metal is poured he tosses small particles into the stream until the mold is filled. At other plants the aluminum is introduced into the ladle immediately after tapping. Then after a time, if the remaining metal in the ladle shows a tendency to be sluggish, a little more aluminum is added to make the metal more fluid. The surprising circumstance is that there can be such a variation in the de-oxidizing technique, and yet the results be so nearly alike.

Welding of defects is permitted in some foundries, but not to the extent that it is permitted here. In most foundries small defects are welded with the previous permission of the customer. However, the British Admiralty, and many private firms do not permit welding at all.

One plant in Scotland makes a practice of cutting up all rejected castings to see if defects actually exist. In most cases no actual defects are found. However, they always examine risers after pouring and if the risers give evidence of insufficient feeding, the castings are cut up and almost invariably under these circumstances blow holes are found in the casting under the riser.

CLEANING CASTINGS.

Most European plants clean their castings by sand blasting, though occasionally they clean them by hand. At some plants, however, castings are cleaned by high pressure (750 pounds) water, and they make a fine job of it. The stream of water is directed from outside the cleaning compartment, which is lighted by high powered lights. I was informed that this method of cleaning is less costly than the regular method and is done more quickly and better.

My visit abroad has definitely convinced me that castings can be made that require no welding. Such castings are being made in large quantities abroad, some of sections as thin as five millimeters or two-tenths of an inch. There is no reason why similar success should not be had in America. However, one thing necessary among many of our steel companies is a change in metal attitude. Too many think the Navy specifications are too severe; that

such standards are not necessary. Too many think that annealing or heat treatment is unnecessary. Too much thought is placed on quantity production and not enough on quality.

Since my return I have visited a number of steel foundries at home, and I have been very much encouraged by a real change of attitude from that which obtained a few years ago. Many of our foundries have definitely changed to metallurgical control. Some have thoroughly up-to-date plants and employ modern scientific methods. Tremendous improvement has been made. However, there are still too many very large capacity plants that have not seen the light. They cannot understand why so much stress should be laid on thin wall sections and castings with no flaws, nor why annealing or heat treatment should be insisted upon. They do not understand that in these days of limitation of displacements of Naval Vessels it is imperative that castings be made as light as strength requirements permit, and that for every pound of casting weight saved we can have an extra pound of naval ship.

The Navy Department has always maintained high standards in its materials. That is why today Navy Standard materials can be purchased for less than formerly was paid for ordinary commercial standards. We cannot afford to compromise in Naval Construction. We must always insist on the best, for the very fate of the Nation may hinge on the quality of its naval materials. And, by insisting on the best, in the end, this best can be obtained as cheaply as the poorer grades are now obtained.

In any case, the steel industry should be the last to object to the Navy's insistence on improvement, since its own success to a large extent was forced upon it by the Navy Department; for, before the development of the Steel Industry to its present size and importance, the Steel Industry preferred to buy its steel abroad. And, only by a provision in the Naval Appropriation Bill of the day (at the insistence of the Navy Department) that all materials going into the construction of Naval Vessels must be of domestic manufacture, was it spurred to make the effort to develop steel in this country. The result has been the development of the largest industry in this country and perhaps in the world. The late Andrew Carnegie, who was to the Steel Industry as Thomas Edison was to the Electrical, definitely gave credit to the Navy for causing improvements in the industry since its pioneer days.

In presenting the foregoing picture of the steel casting situation in Europe, the intention is to give a fair general idea of European practice. Mistakes may have crept in and for these I ask indulgence. It is not unlikely that real steel makers will find more in the picture than I did. Criticism of American methods is intended to be constructive, with a view to persuading those foundries in the United States which have not done so to adopt scientific methods. If by adopting such methods sound castings can be made, the expense of patching them is eliminated and rejections reduced, and I am quite sure a readier market can be found for the better product.

There is no real reason why steel castings of as high a quality as those made anywhere in the world cannot be produced by our own Steel Foundries.

STEEL CAST RESEARCH AT THE NAVAL RESEARCH LABORATORY.

By Commander E. D. Almy, U. S. N., Member.*

Anyone who has been concerned with Navy steel castings either as a producer, inspector or user, must be favorably impressed with Captain Shane's excellent and instructive paper on European steel castings. Since the Naval Research Laboratory has been engaged in a steel casting research program for more than two years, an outline of that program and a summation of steel casting practice and equipment in the United States, may be of interest.

Early in 1930 consideration was first given to a steel casting research problem at the Naval Research Laboratory. Interest in this problem was greatly stimulated by the then recently perfected gamma ray radiography which was the first important contribution of a young but ambitious Metallurgical Division at the Laboratory. It provided the means for ready and economical discovery and exploration of defects in steel castings up to ten-inch sections. This method was looked upon as an effective method of research, designed to improve the quality, *i.e.*, to learn the causes for defects and means for their elimination rather than as a routine inspection method.

Early consideration of a steel casting research problem disclosed that the Laboratory was deficient in four important fundamentals: First, lack of equipment; second, lack of funds; third, inadequate personnel; fourth, no very clear conception of what could or should be done.

The material Bureaus contributed to the extent of purchasing an electric arc furnace of one-fourth ton per hour capacity. We normally pour about 800 pounds per heat but have capacity for about 1500 pounds. Four small induction furnaces and crucible pits are also available.

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Commander Almy in his paper, and Dr. Canfield and Mr. Briggs, in the two following papers outline to some extent, the research being undertaken by the Navy in its Steel Casting Program. Mr. Briggs also makes some comparisons between practice abroad as described by Captatin Shane and practice in the United States.

Most careful consideration was given to selection of personnel. We predicated our specifications on a broad and thorough scientific foundation. We did not search the steel foundries because we wanted to be free from bias, prejudice, or preconception. We wanted primarily scientists, and, if possible, scientists with metallurgical training. After a very careful survey we have secured what we consider an excellent staff for the purpose. The program is under the general supervision of a physicist as superintendent of the division of metallurgy. In immediate charge are an associate metallurgist and an assistant physicist. All three, of course, have graduate training in metallurgy. The staff is entirely competent technically and, of perhaps equal importance, they are young, unprejudiced and ambitious. Upon this we base our hopes that their research will be free from dogma and will be based upon scientifically proven facts.

Our early conclusions were that the whole foundry business had been cursed with mass production and price per pound. Also, that foundry practice had been based on experience rather than on scientific facts. We believe there is too much guessing. As shown in Captain Shane's paper a given method will produce fine results in one foundry and be discredited by another. It is a fair assumption that neither foundry can with certainty attribute results to the factor under consideration. Too little is known of the fundamental effect of each factor and in general the control is too inexact to permit authoritative analysis. It is our aim to establish a sound technique so that we will have a scientifically exact control of every factor entering into the final casting. This is a feature in which the steel casting industry is woefully lacking. We believe that by controlling our variables we can determine the fundamental effect of each. Thus we hope to establish sound laws and prove them both scientifically and practically.

Early in our program we proceeded to study the variable literature and now have, we believe, the most complete steel casting library existant.* During this period we also visited the various foundries east of Chicago and within the last year those on the Pacific Coast, and are therefore familiar with the equipment, per-

* A Bibliography on Steel Casting Design, prepared by the Naval Research Laboratory, is published in the Notes of this JOURNAL.

sonnel, and practices existing in the United States. Our equipment for our purposes is not paralleled elsewhere in this country, and probably not abroad.

We gave a great deal of thought to our program, *i.e.*, of what we should do, and how to do it. We prepared a preliminary program and submitted it to leading metallurgists of America. As a result of their comments, constructive and otherwise, we revised the program and now have, we believe, the most comprehensive constructive program of steel casting research in existence. This program as well as steel casting practice and equipment in the United States will be outlined by members of the staff in separate papers.

We have, we believe, supplied our deficiencies in equipment, funds, personnel and a research program. Our equipment, up to the capacity available, is a matter of satisfaction to ourselves as well as favorable comment of others. Adequate funds are always a matter for serious consideration, and particularly so at the present time, but we hope amounts available will continue to meet our minimum needs.

The soundness of our research program must necessarily await proof. As in almost all difficult research endeavors concrete results are apt to be slow. However, our continued attack of this problem increases our confidence in ultimate success. Captain Shane's paper, in general, confirms our conclusions.

OUTLINE OF STEEL CASTING RESEARCH PROGRAM AT THE NAVAL RESEARCH LABORATORY.

By Dr. R. H. Canfield.*

In 1916, at a time when public attention was focussed on the events of the world war, an event occurred at Quebec which would have excited greater interest in quieter times. The center span of the great cantilever bridge then nearing completion was being raised from barges on which it had been floated from the site of its erection. This center span was itself a truss bridge of 640 feet span and weighed over 5000 tons. It was to be raised by means of a system of linked eye-bars to a height of 150 feet above the water. To eliminate twisting strains on the shoes of this truss during erection, each corner was supported by a pair of crossed rollers forming a sort of universal joint. Between the crossed rollers was a cross-shaped shoe which was of cast steel. Naturally these castings had been as carefully inspected as was possible at that time, and pronounced satisfactory.

Nevertheless, when the truss was some feet above the water, one of these cast steel shoes failed and precipitated the entire center span into the water. This catastrophe entailed the loss of a million dollars and a delay of over a year in the completion of the bridge. The final erection occurred in 1917 at a time of still greater public preoccupation; it followed generally the same scheme as originally planned with the exception that the cast steel shoes were replaced by articles assembled from forged steel and rolled sections. It was perfectly successful.

The broken casting which was the cause of this catastrophe has never been recovered from the river, so it is not possible to say positively that the failure was due to a concealed defect in the casting. It has, morever, been asserted that the design itself was defective, and that the actual stress at certain points amounted to 20,000 pounds per square inch.

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The fact remains that a casting failure caused the accident and that the prevailing methods of manufacture did not give assurance of internal soundness, while inspection methods were inadequate to detect internal flaws if such existed.

Matters are only a little better at the present day. We are now supplied with the methods of X-ray and gamma ray radiography by which we can discover defects in castings important enough to warrant the expense of such scrutiny. The only trouble is that almost every such examination reveals a heart-breaking number of larger or smaller tears and cavities, and starts a long-drawn argument as to whether they are really serious enough to warrant rejection, and whether they can be repaired by welding.

If steel casting technology had arrived at a stage comparable with other metallurgical arts, the foundryman would know in advance that his casting would be entirely sound. He would know it because he had tested his molding sand and adjusted its properties so that they were correct; because he had computed the size and location of the risers required, and knew they were adequate, because he had tested his steel for temperature and fluidity and knew that it was correct for a casting of these dimensions.

But, you say, all these technological precautions and measurements will increase the cost per pound of our castings. True; but is sound workmanship not worth paying for? Would you accept a new mahogany table if it had scratches and mars on its surface, or a new house that had holes in the plaster, and shaky partitions? No; you would say you wanted good workmanship even if it did not affect serviceability and even if it did cost more. Why then should you not demand perfect workmanship in steel castings on which the safety of a whole ship may depend? Moreover, the allowances for defects which designers feel compelled to make in large castings result in the addition of many unnecessary tons of weight. This can be eliminated when cast steel enjoys the same confidence as rolled steel.

As a matter of fact, Captain Shane's paper shows us that such demands are made, and met, in European casting technology. And they are met by methods such as mentioned above, *i.e.*, trained and expert technical supervision. There is no panacea for castings, no

mysterious mixture of which a teaspoonful tossed in the ladle will ensure freedom from hot-tears and blowholes. Europe displays even more diversity in details of foundry practice than America does. The one common factor in great European foundries is detailed engineering supervision of every operation on the foundry floor; and that one factor is what many American foundries lack.

Furthermore, in comparing American with European casting technology, one must not lose sight of the element of casting design. The designer can do as much as the foundryman in assuring a successful casting, by proportioning his design with an eye to foundry operations, much as a structural steel detailer is trained to make his drawings with an eye to the exigencies of the fabricating shop.

There is a reason for this lack of real technical control, and that reason is lack of numerical data on which to base it. Most molding problems are thus at the present day subjects for judgment rather than computation. It is one of the main objects of the Naval Laboratory's research program to acquire some of the experimental numerical data necessary to make such computation possible.

To explain more thoroughly this program let me classify the defects of castings according to their causes:

First, there are unsoundness and porosity due to metal of improper composition. Their cure lies in well known metallurgical methods which we need not discuss here.

Second, there are porosity and sand pockets whose cause lies in the molding sand. Either the sand was unsuitable to begin with, or the mold was improperly tamped or dried, or there was some other failure incident to sand conditions. The cure lies, of course, in *sand control,* which means frequent laboratory tests of the sand used, and appropriate treatment to bring the sand up to standard. Our part in the development of this feature has merely been to assemble data from studies made by others, and to install a complete modern sand-control laboratory where these methods may be practiced and demonstrated to others. Such a laboratory is, of course, useless without the presence of proper machinery in the foundry to screen and reclaim used sand, and to mull together necessary blending mixtures. This machinery also, on a small scale, is part of our equipment. Sand control may furthermore

mean the use of more expensive materials; this necessity is part of the cost of good, as compared with slipshod, workmanship.

Third and last type of failures consists of hot tears and shrinkage cavities which may be traced to design; either the design of the pattern itself or the design of the mold, in which should be included proportioning and placing of gates and risers, number and position of chills, and compressive resistance of cores and parts of the mold which resist contraction of the steel. It is these latter problems which our object is to try to solve. There follows a brief outline of the kind of experiments we are making to get this information.

First of all we are studying the rate of solidification and cooling of steel in the mold, as influenced by the type of mold whether green or dry sand, the surface area of the casting, and other factors. One series of such experiments, for instance, is a set of solid spheres of different sizes. At various times after pouring, the metal remaining liquid in the mold is poured out; the rate of solidification is given by the wall thickness. Another series consists of a record of temperatures in different parts of castings, obtained by burying thermocouples in them.

In another series of experiments we are recording the contraction of a casting when its contraction is resisted by a heavy spring, and particularly the tensile strength at very high temperatures. In this way we are securing data of value for the study and prevention of hot tears.

Still another series of experiments deals with castings which we make from patterns intentionally designed to show the effect of sudden changes of section, sharp interior corners, and so on.

The ultimate object of this work is the assemblage of a body of definite numerical data for the use of casting designers and foundry engineers, from which questions such as the following may be answered:

Just how abruptly can a one-inch section change to a two-inch section?

Just what outside and inside radii should be used in a right-angled corner formed of one-inch sections?

The accumulation of this data will require a long time. No commercial firms are engaged in it, and few are equipped for it since

it requires the resources of a general physical and chemical laboratory in addition to those of a metallurgical laboratory.

In this discussion no mention has been made of studies of steel from a metallurgical standpoint, and it is no part of our plan to make such studies, believing that this branch of the art is already well advanced and its further progress in good hands. In fact, we believe that the physical properties of metal as determined from test specimens have perhaps been overemphasized at the expense of soundness of the castings themselves.

AMERICAN STEEL FOUNDRY PRACTICE.

By C. W. Briggs.*

Captain Shane has very ably pointed out the interesting features of the various European steel foundry practices and has given us an insight as to the European methods of steel casting manufacture.

It is my plan to outline to you some of the features of the American practice and to show how they differ from the European.

EQUIPMENT.

In 1929 when production was at a peak in the steel casting industry, basic open hearth led the processes making steel for casting purposes.

Basic open hearth, tons	525,000
Acid open hearth, tons	485,000
Electric (Acid and Basic), tons	374,000
Bessemer, tons	27,000
Crucible, tons	794

The acid electric practice constitutes about 75 per cent of the production of the electric process. This process has been gaining considerable favor, especially in 1918, and the total tonnage of steel as produced by this process has increased remarkably. The large open hearths are still favored as large castings can easily be poured.

In the last few years considerable thought has been given to the control of the operation on open hearth furnaces. Temperature control of the checker system has become automatic and forced drafts have been practically controlled. These features make the present open hearth furnaces the most accurate melting furnaces of their type in the world. The control of the electric furnaces with the many power taps have tended to give a more uniform temperature control.

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The core ovens and mold drying ovens are of the finest type that can be produced. Usually they are very carefully controlled as to temperature and as to fuel. One of the finest ovens of this type is being operated by a steel casting manufacturer in the Eastern district. The oven is 230 feet long, is gas fired and is run at 450 degrees F. There are 5 racks running through the oven at different speeds. The cores are placed on the racks according to the size, the largest cores on the slowest rack. The speed of movement of the cores through the oven is from 45 minutes to 9 hours, depending on the size of the core.

The annealing furnaces are, in general, mostly of the car type and are usually oil fired. The car type furnace fits in nicely with the American practice of normalizing castings instead of using the full anneal. I shall speak further on the normalizing practice in this country when I consider the subject of heat treatment.

The molding equipment that is available in this country is of the very latest design and is extremely helpful in mass production manufacturing. We have squeeze machines, combined jolt-squeeze machines, jolt-ramming and sand slingers. These machines are especially adaptable in the assembly-track type of foundry where material is all brought to one place and machines can be set up in the production cycle. There are certain features about the use of these machines. They usually give definite mold characteristics such as a uniform mold hardness throughout a mold, and from mold to mold. Of course, then, too, the hardness of the molds can become much greater than they otherwise would have been if hand ramming had been used. This in many cases is distinctly a disadvantage.

SAND.

There is no sand in this country that is equivalent to the European Compo. Of course, in some cases this may be a disadvantage. However, it is felt that if a synthetic sand of washed quartz grains is used with a good grade bonding material a very high refractory sand can be produced that will give excellent results. The natural bonded sands are used fairly extensively in this country, depending on the proximity of the deposit. However, it is easier to control the physical characteristics of a sand

that is synthetically bonded and a greater regularity is obtained. One organization gets a fairly good refractory sand nearby that has a low compression strength. They build up the strength further by mulling with it percentages of bentonite; in other words, the sand is of a semi-synthetic nature.

The very surprising thing is the large amount of green sand that is used in the American steel casting plants. In nearly all the high-class small casting plants green sand is used, and in plants where large and small castings are made, two types of sand are used, the dry sand practice in the large molds and the green sand in the smaller ones. The green sand practice as employed at two foundries in the Eastern district is the use of a number 40 washed silica sand bonded with bentonite, corn flour, wheat flour, or sugar products, and 3 to 4 per cent water. These are mulled together for definite periods in order to obtain the strength desired and then distributed to the molding floor. Sand thus produced will act as molds for metal poured that day or the next day at the latest. Green sand is more collapsible than dry sand and is more easily crushed by the casting in contracting. This is especially important at the solidifying temperatures.

Collapsible cores and molds have received considerable attention, especially in the best foundries. In some cases the entire mold back of the facing sand will be made up of cinders, coke, straw, etc., in order to insure complete collapsibility. Cores are constructed in the same manner. In fact, most cores should be made as collapsible as possible as they are usually surrounded by metal and if not of a collapsible nature may very easily crack the casting.

At one plant where they cast alloy steel pipe, they use two types of collapsible cores. One method consists of building the core up on a chain. As soon as the mold has been poured the chain is jerked out of the center of the core by a crane and the core has room in which to collapse. In another case they build a facing sand around a hay rope. The temperature of the core after the metal has been poured around it is so great that it burns out the hay rope and allows the core to collapse.

At another plant all sand cores are made in halves. After baking, the sand is removed from the center of the core, thus providing collapsibility. This is a very good practice and is carried on by several other organizations.

Two foundries in Pennsylvania and one in the Chicago district use a quantity of green sand cores. In this case they have a complete green sand practice. Green sand cores have found rather wide application in industry but careful handling must be provided.

Relieving blocks are useful in helping to make molds collapsible. Two organizations producing railroad castings use this method. Blocks are molded in place and as soon as the casting has been poured a crane pulls out these blocks, thus allowing the metal to contract without withstanding excessive mold resistance.

There are other precautions taken in molding such as care with gates, shaping of heads, etc. A practice of a foundry in the Detroit district and one in Eastern Pennsylvania is to mold the gates so that there will be no corners. In this way the amount of sand that is washed off into the mold is kept very low. In some cases these gates are made up in sleeve form and dried and then placed in the mold.

One reason that collapsible molds are not used more in this country is that the sand is all shaken out and reclaimed. When cinders, coke, etc., are used this makes the reclaiming process rather difficult as such material must be separated or it will lower the refractoriness of the sand.

CORE MOLDS.

Core molds have become rather popular in production shops. The molds consist of an assembly of dry sand cores. The cores are molded at one place, dried in the core oven, and then brought to the job where an assembling crew builds the mold.

RECLAIMING.

A very important phase of the modern steel foundry is sand handling and sand reclaiming. The molds are usually shaken out over a pit into a primary crusher. These shake-out pits are very good as they specify a definite place for molds to be shaken out; not all over the shop, as is sometimes the case, which results in a shop having various piles of heap sand with a varying number of characteristics.

The sand, after being broken up, passes under a magnetic separator and hence into the mullers where the sand is broken down

into its component grains. From the mullers it goes to a reclaiming system where air, water or vibratory screening devices are used to remove the fines, and then back to the muller for rebonding and water addition. The muller as is seen is a very handy device and almost every foundry has one or two. One company has three large mullers that are in practically continuous operation. In these mullers about 1500 pounds of sand can be mulled. At another company 1800 pounds is mulled every four minutes.

Sand hoppers and sand conveyor systems are very helpful as sand is delivered to the molder at all times. This system can be seen in several foundries.

In order to have a well-controlled foundry sand, certain test equipment must be on hand and sand tests should be run hourly. The most important tests are those for compression strength, permeability and moisture content. Methods for determining the sand grading should also be at hand.

It is practically impossible to run a green sand practice without having accessible sand control equipment. One of the shortcomings of Navy foundries is their failure to see the necessity to install this equipment, as it is only by the knowledge of such test conditions that any definite improvement can be made in foundry sands. It is needless to point out that foundry sands are exceedingly important in the manufacture of steel castings.

STEEL.

The practice in this country is to use a very fast melting cycle. This is quite different from that of the European practice as Captain Shane pointed out. The advantage of the fast-melting practice over a slow practice is that less carbon is lost by oxidation in the melt-down period. It might be quite possible that the slower melting practice results in producing better grade steel but on that point we have very little data. It might help in some of our practice as in a great many cases the steel making in this country is merely a melting down practice and not one of steel making at all. This is especially true in the acid practice. Very little attention is paid to slags, and as there is no elimination of phosphorus or sulphur, the practice merely results in melting down and pouring out. Perhaps if in this case more care were taken with melting

down, a better steel would result. It is my opinion that a number of American manufacturers of steel castings do not give enough time or thought to the making of the steel. We have seen how important the bend test is in European countries. In this country much more importance and stress is placed on the yield point and the reduction of area. And though the bend test is not mentioned so often, I believe that excellent bend tests are practically always obtained. The average physical properties obtained in this country for the usual run of castings are as follows:

Tensile Strength, pounds per square inch	72,000
Yield Point, pounds per square inch	40,000
Elongation 2 inches, per cent	30
Reduction of Area, per cent	50

The average chemical analysis is:

Carbon, per cent	0.25
Manganese, per cent	0.60—0.70
Silicon, per cent	0.30
Phosphorus, per cent	0.04
Sulphur, per cent	0.04

It will be noticed that the carbon content is about 10 points lower than the general European practice as Captain Shane has pointed out. The manganese is also about 10 points lower and the silicon about 5 points lower than the European practice. This difference may have a marked significance as regards the finished product but no definite statement can be made as there are no correlated data on hand that would substantially prove this point.

Speed with a great degree of accuracy has been obtained in this country on control analysis. Carbon and manganese can be obtained in 10 minutes. Various methods of conveying rapidly the sample from the melting floor to the chemical laboratory have been installed such as aerial trams, pneumatic tubes, and the like. Solutions are kept hot, ready to add to the sample, and the analyses are turned out quickly with precision. The results are returned to the melting floor by telephone, or, as in one case, the chemist broadcasts the results through a loudspeaker and the results are heard over the entire melting floor.

Some plants use a steel of a different analysis than that given above. For example, at one plant a silicon content of 0.80—0.90 per cent is used. They claim that they get much greater fluidity and that their physical properties are very good.

The problem of fluidity is important. In fact, much more important than most steel casting producers realize. It is true that the user of the acid practice claims greater fluidity than the basic practice, while a basic practice operator will claim greater fluidity for his own produce. Up to the present time little has been done to obtain reliable information on the subject. Two organizations have worked somewhat on fluidity using a modification of the Saeger horizontal spiral mold and they have reported that using the same practice, the same furnace and all other things controlled as nearly as possible, that varying degrees of fluidity are obtained. No steel foundry in this country, to my knowledge, uses a fluidity test before pouring.

DOUBLE PROCESS MELTING AND DEOXIDIZERS.

In some plants a double process is carried on. One of the plants in Western Pennsylvania uses a tilting acid open hearth furnace to make a 0.30 to 0.35 per cent carbon steel and then pour a portion of the charge out and the remainder of the charge they make a low carbon 1.50 per cent manganese alloy. Such production methods are not always the best, though excellent results are claimed for them.

The deoxidizers are much the same the world over. Aluminum, ferro-silicon and ferro-manganese are the most important. Ferro-titanium, calcium silicide and sodium are also being used. There are many ideas about the time and the method of addition. Some additions take place in the furnace, others in the ladle and others even in the mold. In general, these practices are the result of experience rather than anything founded on scientific correlations. Herty's work on deoxidizers for the open-hearth furnace is the only reliable source of information. His experiments have led him to believe that an iron alloy of manganese and silicon added to the furnace seems to be the best deoxidizer.

The pouring ladles used in steel casting manufacturing are mostly bottom pour, especially for the large castings. The small

castings are poured from the top pour ladles and the teapot ladles. In the latter case the metal is poured from the ladle into hand shanks and then carried to the molds.

HEAT TREATMENT.

The heat treatment of steel castings in this country consists mostly of normalizing. Heating in the furnace, holding for a predetermined time and cooling in air. In many cases this treatment is followed by a draw at temperatures of 900—1100 degrees F. It is claimed that by the normalizing temperature greater yield points are obtained and that the furnaces are released for further treatments. In many cases two cars will be available for each car type furnace so that while one car is in the air cooling another car can be in the furnace heating up. In this way greater production is maintained. In some places, one big plant in particular, no heat treatment at all is given to the castings. At another foundry the castings are shaken out of the sand as soon as possible and while hot are transferred to an annealing furnace that is up to temperature. The castings are then slowly cooled. There are many different practices of heat treating but the full anneal is not the most widely used practice. The industry feels that the Navy's methods of heat treatment are considerably behind the times; if that is the case, some of the European heat treating methods are considerably ancient too. It is rather difficult to prove this point as steel with good physical properties comes from both methods.

CHILLS.

The steel founders of this country are sadly in the need of education on the use of chills. Chills from those of the horseshoe type as used in Europe to bars ½ inch by 3 inches or maybe even larger have been used in this country as internal chills. To use internal chills and to use them properly is a science and not an art as most foundrymen believe. Chills of all shapes are used. We would do well if we limited all internal chills to horseshoe nails and some section spirals. Chills improperly used have been the source of more trouble in the foundry than they have corrected. The Navy's foundries, likewise, have not given as much consideration to chills

as they should. Some foundries are using a large number of external chills, but care must be taken to form them to the shape of the casting. At a foundry in the Eastern district the external chills are cast fastened on the main casting. Thus the chills cast on a casting will be used in molding the following one.

CLEANING CASTINGS.

The operation of cleaning castings has progressed so much in the last few years that considerable speed can be obtained. Steel shot have somewhat supplanted the sand blast, and the grinding wheels are so readily manipulated that a cleaning room can be run on a time production basis. In some plants two cleaning rooms are provided, one for the cleaning of small castings and the other for large castings. The use of synthetic sand has reduced cleaning costs considerably.

In some cases there is considerable welding done on the castings and in other cases practically none. It has been the general plan of the producers to finish castings with surface conditions as perfect as possible.

NON-DESTRUCTIVE TESTING.

Many manufacturers of steel castings have used X-ray radiography as an inspection medium of their castings. There are many jobs today that require X-ray radiography. Considerable interest has been given to the Navy's method of gamma ray radiography and various large steel casting organizations have become familiar with its use and feel that it is a real tool in the hands of competent foundrymen. The staff of the Naval Research Laboratory feels that its greatest benefit is not as an inspection medium but as a method of sound casting production. Pilot castings should be radiographed completely and in this manner the location of defects can be found and the molding and casting procedure so modified as to give perfect results.

PERSONNEL.

I should like to say a few words about the foundry personnel. The foundry superintendent is in control of every phase of the foundry practice in this country, and in general the foundry super-

intendent is a practical man, a good molder, and perhaps a good practical steel melter. The Engineer or the Metallurgist has little actual control over plant supervision. More technical supervision and control would help the foundry immensely. The main concern in the country has been, of course, to develop the machine and to increase production. It is rather difficult to get trained young men to become apprentices in a steel foundry as they dislike the idea of the low pay they are required to take, and foundry work has been associated with the class of dirty work. We have apprentice systems in this country but they are far from the type that is needed to train men to be technically trained plant operators. Of course, the organization is not entirely to blame that the grade of men that accept apprenticeship are not of the right caliber. However, I believe more constructive thought could be given to the development of personnel. The steel foundry today needs technically trained men who know a great deal more about theory and less about the mechanical application of molding. An organization that can boast of a consultative board consisting of practical men, and technical men, where the problems of the foundry are considered and solved, will produce a higher grade product.

DESIGN AND DEFECTS.

It is needless to say that the design of a steel casting has considerable to do with the condition of the finished product. It is the opinion of many that most of the defects that are found in steel castings are the result of the casting design. If a knowledge of the casting conditions that steel undergoes were in the hands of casting designers, then we could expect better castings. It is not, of course, the fault of the designers especially that they have no book of rules by which they may design a casting. It is more the fault of the steel casting manufacturers that such a set is not available. How many casting designers are technical men who have studied the factors involved in the manufacture of steel castings? How many designers have conferences with technical men to find out the practicability of their design? Of course, the answer is—very few. A number of the casting organizations have in their staff casting designers that really look at the casting from the manufacturer's viewpoint as well as for the strength characteristics, but these men are in the minority.

The Navy is as badly off in this regard as other organizations. Some of the castings of Naval design are of such a condition that there is little wonder at the defects found. These designers undoubtedly know perfectly the structural features necessary in the casting but they have not considered the variables arising in the manufacture of that casting. Of course, it is not their fault as they are not familiar with that phase. The fault lies in lack of technical information and lack of intimate cooperation with the casting manufacturer. The Naval Research Laboratory, with its small staff in steel casting research, is attempting to make some headway in this field with the idea of collecting technical information. The research will be long and tedious as there are so many established ideas and prejudices that must be shaken down to a firm scientific basis.

RESEARCH.

There is a great need for research in the steel casting industry. Some of the commercial organizations are attempting to carry on one phase or another in this field. They have, however, been more interested in their own special products than in basic underlying problems. The American Foundrymen's Association and Battelle Memorial Institute are also interested. The former has done considerable in its activities on the research of foundry sands and the latter has been interested in alloy steel castings. All of these groups are necessarily helpful to the industry but it is thought that the Naval Research Laboratory's plan of research is more basic and in time will prove more helpful.

There is another type of technical control that is available. In the industry there are two organizations, the Steel Casting Development Bureau with Mr. George Batty as Director, and the Electric Steel Foundries Research Group with Major Bull as Director, that offer their constituent foundries valuable service. These organizations consist of competitive steel foundries that have come together and established a central organization for dissemination of technical information. They have recognized the need for technical control. Through this organization they solve problems involving sand technique, molding practice, melting methods and the various problems that daily present themselves in

a steel casting industry. It is noteworthy to point out that the organizations of these groups compete against each other for their business. Individually, they would be unable to maintain a technical staff but collectively they can do so. The result is that they deem technical information is not competitive in nature and that by it they are able to produce better steel castings not only for the good of the industry and their consumers but also for the good of their own name.

It is interesting to note that while competitive organizations can do this, the Navy does not attempt to correlate the technique, melting and molding practices of its various foundries and in this case the foundries are all under one general organization.

As can be seen the American practices do differ somewhat from those of the European, but this does not mean that good steel castings cannot be produced in this country. In fact, thousands of tons of excellent high grade castings are turned out yearly. But there are also many cases where better castings can be produced. Such production can only be attained through thorough knowledge and application of correct casting design, technical supervision of foundry manipulations, and diligent research.

DISCUSSION OF CAPTAIN SHANE'S PAPER: "A BIRD'S EYE VIEW OF THE STEEL CASTING SITUATION IN EUROPE."

By Mr. George Batty.*

I am greatly pleased to have had the opportunity of scrutinizing Captain Shane's interesting manuscript and am moved to make comment upon it.

There is, in the paper, what I take to be a friendly—but nevertheless direct—indictment of the steel-castings manufacturers of this country and the comparison, drawn by the author, of steel castings production in this country and in Europe is definitely adverse to us, notwithstanding his statement that American steel foundries now reveal a real change of attitude from that which obtained a few years ago.

On the other hand certain makers of steel castings in this country insist that a user of steel castings is entitled only to what he pays for and that if a low price only is paid, a low grade quality only is to be justifiably expected. Probably this is no place to dwell upon the system of the acceptance of the bid of "the lowest reputable bidder," yet my personal experience has shown that the practical man in the foundry—the foreman or superintendent—is burdened with a cost limitation when he embarks upon the production of keenly cut-price castings. The natural result is that such a man, in order to retain his job, cuts corners, and thereby cuts quality. This is rank unfairness to the practical man and to this unfairness is added the indictment that he is incompetent and must necessarily be supported and buttressed by technicians and scientists in order to produce even decent castings. This is no argument against the employment of the technician, or the engineer as Captain Shane defines him, but is a defense of the practical foundrymen who can—and on many occasions do—produce excellent steel castings.

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Captain Shane's paper is interesting, informative, and inspiring. Its major inference is that the Navy Department intends to have thoroughly satisfactory castings and it necessarily follows that there must be, in the production of these castings, an augmentation of the art and the science of castings production as compared with that which has pertained in the past.

Scientific and technical control of the various details of procedure that go to the production of satisfactory castings is, in this country, available to the users of steel castings; and to assume that the Europeans have better technicians in the foundry industry than have the United States of America does not appeal to the writer as being necessarily correct. If we survey the work that has been done in relation to the production of steel and of castings by such men as Hall, Bull, Melmoth, Simms & Lilliequist, Lorenz, to mention only a few, together with the beautiful work by C. H. Herty, Jr., on Steel Making, we must believe that this country is adequately equipped to produce castings of a quality equal to the best obtainable elsewhere.

The injection of the scientist and the technician into the foundry industry is welcomed by all intelligent, practical foundrymen and it is realized that the non-destructive inspection of castings by X-ray or Gamma-ray will result in improved foundry technique and in a superior foundry product.

Some few years ago Mr. H. J. French—now of the International Nickel Company—remarked that the foundry industry was afflicted with a multitude of opinions and was deplorably lacking in facts. This statement was, and is, substantially true. It will always be so because no matter how much we know there is still much more to be known. Although Mr. French's opinion was expressed in particular reference to an American foundry investigation it applies, in the light of Captain Shane's paper, to European foundries.

We find that one manufacturer uses a large number of integral, or cast-in, chills of the horseshoe nail type while another declines to use that type of chill and prefers to use enormous risers to promote soundness.

The foundry which uses a large number of cast-in chills attempts to justify itself by sectioning a casting and showing what appears to be perfect welding of the chill inserts. The chills or horseshoe

nails must be of a composition substantially different from that of the cast metal and although fusion has taken place it cannot have produced within the mold a truly uniform metal. It necessarily follows that in such a system of production a test coupon composed entirely of cast metal—without any cast-in chills—cannot possibly be so nearly representative of the casting as is a coupon attached to a similar casting which contained no integral chills.

The question of the relative merits of internal—cast-in or integral—chills as compared with external chills is something more than a mere difference in technique. I believe that the use of internal chills is a definite encroachment upon the potential qualities of the cast metal and have committed myself to the principle that cast-in chills should not be used when it is possible to avoid their use by applying external chills or by a modification of gating and heading procedure. To this must be added the suggestion that a modification in design may eliminate to some extent the necessity for the use of chills, and there is also a reservation to make in the case of such things as bosses where an integral chill is later removed entirely by a machining operation.

It is conceded that it is not always practicable to deliver feed metal to certain heavy sections of a casting and resort has been made to the use of internal chills with what appears to be satisfactory results. I prefer that external chills should be used but I am impressed by Captain Shane's statement that presumably satisfactory castings are made in one foundry where an enormous number of small integral chills are used. One wonders what the physical properties are at certain heavily chilled parts of the casting and it would be interesting to compare these with the physical properties cited as acceptance minima on test pieces which must be composed entirely of the cast metal.

A somewhat startling deviation from ordinary procedure is cited by the author in his statement that at Feignies "Two barrels of water were upset on the risers" immediately the ladle had left the mold. It is difficult to accept the suggestion that feeding was complete within a few seconds of the completion of pouring if the casting was of heavy section, and if, by any careful adjustment of pouring temperature and pouring speed it could be possible to accomplish the whole of the "liquid contraction" during the pour-

ing operation, the two large risers mentioned would appear to represent nothing but waste.

Unless the pouring temperature is very low there must be some considerable change in volume of the metal in the mold before solidification is complete. It is the function of risers to deliver to the casting the metal to compensate this volume-change. It seems possible that the Feignies castings may be seriously afflicted, in places, with internal defects of the type under investigation by Briggs & Gezelius. It may be, however, that the functioning of the risers is not seriously impaired by having the water thrown upon their upper surfaces and that the explanation offered to Captain Shane comprises only an opinion and not a fact.

At this time it appears opportune to state that substantial investigations are being made, in the United States, which are devised to enhance foundry technique. The system is orderly;—

1. Establishment of fact.
2. Correlation of data.
3. Evolution of formulae.
4. Application of formulae as production procedure, and must result in the steady improvement of the quality of castings.

It is not disputed that some of the criticisms listed by Captain Shane are justified and in particular I think he is correct when he deplores the American system of hurrying production processes. In steel making practice this may be especially true because cleaning a steel is, to some extent, a function of time.

Geoffrey Chaucer was no steel maker but he might have been addressing us directly when he wrote " He hasteth wel that wysely can abyde." There is a period in each steel making process when we must be content to allow Time to exercise its function.

It is interesting to note the comment " fluidity is not necessarily obtained at the same temperatures." Melmoth was, I think, the first to note the abnormality in electric steel, as compared with acid open hearth steel and converter steel, which has come to be known as the " over-reduced condition." This abnormality seems to be related to the behavior which McCance noted in the production of certain chromium steels, silicon steels, and chromium-silicon steels. McCance suggested that these particular steels evolved, as light,

an abnormal amount of heat at the surface exposed to the atmosphere. A similar condition is to be observed on plain carbon steels produced in either the acid or basic electric furnace and this condition is believed to be inimical to the production of the best type of castings. Not only does this metal fail to run the castings sharply, but, in the larger castings, this abnormal evolution of heat from the exposed surface results in the formation of a solidified film which may be overflowed, within the mold, by liquid metal—ferro static pressure of superimposed metal in the gate serving to burst the film at its weakest part—and a film or films of oxidized metal entrapped within the casting.

In this country we are not unaware of these phenomena and in many foundries tests are made to determine not only the temperature of the metal but its fluidity and its ability to stand exposure to the atmosphere in the process of delivering metal to the molds or exposure to the atmosphere in the molds in the process of running the casting.

It may be true that practically every foundry in Europe which Captain Shane visited is scientifically operated but I decline to believe that Old Man Noah still runs most of the American foundries. I submit that, at the very least, we have Ham, Shem and Japhet. I do not claim that we are operating under conditions that even approach the ideal and Captain Shane makes an excellent point when he reveals the European practice of having the founder produce the pattern in a manner peculiarly suitable to the system upon which the foundry will produce the casting. In this country so many users of steel castings wish to buy the cheapest possible type of pattern—which is nothing more than a wooden replica, slightly enlarged, of what the casting is to be in form. Thus, we have, added to the indictment of indecent haste, the indictment of deplorable and dangerous parsimony masquerading in the guise of virtuous economy.

In reference to the citation by Captain Shane of the opinion expressed to him in Europe concerning the values of various melting processes in respect of the quality of the ultimate product there is bound to be some acute divergence of opinion. If we consider the physical chemistry of steel making we shall find that the essential reactions are conducted in practically the same manner in each

acid process and that the variations in the quality of the product might more justifiably be attributed to the practitioners than to the processes. As instance, the convertor process has been attacked in this country. Captain Shane notes that "The French Government does not permit any convertor steel to be furnished and except for unimportant castings, convertors are not used even for commercial work"—yet some few months ago Mr. Jules Deschamps of Kryn & Lahy, England, quoted to me results obtained by him from his convertor metal that would be good, for the composition, in any process. He generously stated that the augmentation of his quality was directly resultant upon the application of materials devised by Dr. C. H. Herty, Jr., and his associates in their recent investigations. It would appear therefore that the American technician is not lacking the honor of acknowledgment abroad. Captain Shane has quoted results from Kryn & Lahy and has attributed the improved results to the adoption of procedure in respect of materials as recommended by Herty and his associates.

Comparisons have been made of acid open hearth steel and acid electric steel but no real unity of opinion has been arrived at by the investigators. Melmoth has written interestingly on this subject.

It seems probable that it would be distinctly difficult to establish as a fact that, consistently, acid electric can be made better than acid open hearth—or vice versa.

When we come to consider basic electric in comparison with basic open hearth we do not have the same parallel of potentialities in general current practice. The basic electric furnace is peculiarly suitable for the production of refined steel from relatively poor-grade base-materials which are high in sulphur and phosphorus. The charge is melted and is strongly oxidized so that a considerable proportion of the phosphorus is taken up by the slag. This slag is poured from the furnace and leaves metal with only a low content of phosphorus. The charge is then subjected to strongly reducing conditions and the sulphur is substantially eliminated from the steel, being taken and retained by the slag. Deoxidizers may be added to the metal in the basic electric furnace.

In basic open hearth practice, however, it is not safe to produce strongly reducing conditions as this would promote the release of phosphorus from the slag and, as a fairly general rule, the metal

from the basic open hearth furnace is tapped to the ladle in an appreciably oxidized condition and is deoxidized in the ladle. Such procedure does not tend to the production of the cleanest possible steel, nor to the greatest regularity of composition.

The author states, "The basic process is the one usually employed because of the lack of pig low in sulphur and phosphorus. In large plants there may be one acid lined furnace to produce special steel," and again, "—in the case of open hearth plants, an occasional acid lined electric furnace is used for special purposes." Also, "Near Liege, Belgium, they state that frequently when they fail with the Siemens-Martin furnace, they have no difficulty with the arc furnace."

It would be interesting to know whether the arc furnace operates the same process—acid or basic—at this plant. It is reasonable to believe that either the basic or acid electric process will produce steel superior to the product of a basic open hearth furnace which is operating on low-grade materials, but the acid electric process definitely demands material of a purer type—lower in sulphur and phosphorus—than that which may be used in the basic process.

All this may make the case against the American steel founder look blacker, for it must be admitted that we have adequate supplies of suitably "pure" materials available for acid practice in either open-hearth or electric processes.

Reverting now to the influence of fluidity of steel in its relation to the production of sound castings, we must concede that while temperature does not positively predicate fluidity it is related to fluidity, and this factor must be borne in mind when devising the gating and heading system to be applied in the production of large or complicated castings. The conception of a casting solidifying "all at once" is fundamentally wrong and, in any case, could not be achieved. We must remember that the steel solidifies almost entirely as a result of transferring its heat to the mold and we must also realize that it is not possible to have such a multitude of ingates to a casting that we could even approximate uniform temperature conditions throughout the mold at the moment it is completely filled. We must rather devise our gating system to give us a temperature gradient in both mold and metal which will promote a proper direction or progress of solidification. By some, this devis-

ing of gating and heading procedure is considered an art; by others it is considered a science, mutable to the application of intelligence and endeavor.

Gating and heading has been an art; it must be a science; it must be taken out of the sphere of inspiration and delivered entirely into the sphere of intelligence. Hence, we must look for improvements in steel castings to the technician and scientist, and I say this without in any way casting reflections upon the artisan who is our practical man. If the European foundries have buttressed their artisans with scientists to the extent proclaimed by Captain Shane, it is logical that their castings will be better than those produced in foundries operating on the assumption that the production of castings is an art and not a science; but it is also logical to believe that castings produced on such a system will be more costly than those produced without the added expense of the scientifically trained foundry engineer or metallurgist.

The quoted details of equipment, materials and processes in melting, molding, core making and heat treatment are not essentially different from those pertaining in American foundries with the exception of one or two items. One item, "speed," has already been commented upon.

Another is the use of "Chamotte." A material is used in England which must partake, to a very considerable extent, of the nature of "Chamotte," as it is produced by grinding to suitable size used clay crucibles and fire bricks. In Great Britain this material is known as "molder's compo," and is bonded with fireclay just as fireclay is used as the bond in the "Chamotte" mixture. This material is used in the production of heavy castings where the mold must have a considerable degree of strength to withstand the ferrostatic pressure of the liquid metal, and must also be of a strongly refractory nature to withstand the thermal attack of the metal in the region of the ingates.

A careful scrutiny of Captain Shane's paper impels me to the expression of the view that whatever he has found good in European foundries can be duplicated in foundries in this country. It may be that in no one foundry would he find the same intensity of scientific application as he has noted in one European foundry, but there is no doubt that the leaven is working and that the United

States Navy can obtain in this country castings of a quality equal to those obtainable elsewhere. We are not unduly tenacious in holding on to our opinions and I believe that as facts are established we are prepared to discard our opinions and operate along lines predicated by the cold logic of fact. At the present time there seems to be, more than ever, a pronounced flux of what we have esteemed technical verities. Some steel founders deplore what they consider the frigid and costive mentality of some users of steel castings in that these users insist upon certain physical properties which do not appear justifiable when the actual service conditions of the component are considered. More and more cooperation between designer, technician, and artisan is to be desired and a more close approximation of the service conditions of each type of casting should be arrived at in order that the best possible material be evolved at the lowest practicable price.

The question of pickling ordinary castings is touched upon by the author quite briefly and I am inclined to agree with his strong condemnation of the procedure.

In writing his paper Captain Shane has courageously come out into the open and frankly invited criticism of his expressed views. He has stated that American practice was bad but now, in some foundries, gives evidence of adopting metallurgical control of what is essentially a metallurgical process. In commenting upon Captain Shane's paper I have assumed that he would welcome open and straightforward comment, and again I would insist that this country has the brains to deliver the goods on an equitable business basis. There is no strange alchemy of mind which leads European foundrymen to correct conclusions, and there is no ineradicable dumbness in American foundrymen. The thing simply resolves itself into a quid pro quo in the terms of a straightforward commercial transaction where the laborer is worthy of his hire. Results can be obtained, but results must be paid for and, being "neither children nor fools, but men in a world of men" we, under indictment, welcome honest, sincere criticism and hopefully envision cooperation with engineers, designers and users of steel castings.

DISCUSSION OF PAPERS ON AMERICAN AND EUROPEAN STEEL CASTING SITUATION.

By P. E. McKinney, Member.*

This series of papers is not only extremely interesting but constitutes the type of discussion of a very important subject which should tend toward closer cooperation between producers and consumers and a mutual realization by each party of the other's problems.

Captain Shane's open-minded and unprejudiced review of the results of his inspection trip to the various European steel foundries discloses no fundamental features of physical equipment or facilities possessed by foreign industries that are not available in this country. This is further confirmed by Mr. Briggs' description of American foundries and their facilities, which indicates, beyond a doubt, that we have in this country a very complete workshop, probably more modern and up-to-date than that of Europe, to be put at the disposal of consumers of steel castings.

In considering the American steel casting industry, we can very properly divide it into two general classes as follows:—

A—Foundries operated by concerns manufacturing machinery, valves, etc., and who use the foundry product in their own manufacturing operations;

B—Foundries operated for production of castings for sale to other industries.

For manufacturers described under class A, this discussion does not apply to any great extent, as in the case of such organizations the management and engineering staffs responsible for quality of the finished product will assure themselves that all details of design and engineering on contributing factors, such as castings, are on a sound and economical basis. We will, therefore, confine this discussion to the latter class of producers, or the so-called

* Metallurgical Engineer, Bethlehem Steel Company.

jobbing foundries. In some instances the same foundry will operate on both classes of work with excellent success on the castings which go into their own finished product and mediocre performance on the products which are sold in the form of rough castings. Such a condition existing in the same foundry operated under practically standard conditions would at least raise the question as to whether other factors than those directly controllable by the foundry management may not be responsible.

It is unfortunate that the average consumer's conception of a steel casting goes no further than the material as shown by the chemical and physical properties of the steel. If difficulty or failure is encountered, in the absence of outstanding physical defects, the first temptation is to undertake an exhaustive series of chemical and physical tests and then insist upon improved physical properties through the use of alloy additions or elaborate heat treatment without even questioning whether the design which the customer or his agent have imposed on the foundryman have made the production of a satisfactory casting impossible. Such a situation offers no incentive toward the development of sound engineering practice in American jobbing foundries. All too frequently constructive criticism offered to a customer before a job is undertaken covering elements of the design which are impractical or unsound is answered by a statement somewhat as follows:—"This is the foundryman's problem and if he is not a good enough foundryman to produce castings from the patterns as furnished, other foundries will do so." Such an attitude will quite naturally tempt the foundryman to assume a fatalistic attitude and he will attempt to do the best job possible without complaint. In event of a failure, post mortem examination will usually disclose some conditions for which the foundryman can be criticized. To counteract such charges, the foundryman in turn will criticize the design, but usually such controversies lead nowhere except possibly to modification of the particular casting in question.

The industrial use of steel castings is largely a development of the present century. In the case of many applications, castings were not a new product but steel was substituted for cast iron or non-ferrous compositions on account of the imposition of the higher stress in modern machinery design. Notwithstanding the facts well known to metallurgists that the solidification character-

istics of steel are entirely different from those of cast iron and non-ferrous compositions, changes involving the substitution of cast steel for the weaker materials has usually consisted of no further changes than an allowance on the pattern for difference in cooling shrinkages. In such cases the apparent assumption of the designer has been that since the old design was entirely satisfactory in service excepting for the strength of the base material, the mere provision of a stronger material, with good physical and chemical properties, should answer all of the requirements.

American engineering practice, through years of pioneering and development work on mechanical equipment, has become remarkably proficient in the design of castings of the materials used before steel castings came into general use, which has been responsible for the building up of traditional practices covering all cast products which are extremely difficult to counteract. The mental attitude of many designers is that of resentment to constructive criticism on the part of the foundrymen, and such concessions as may be granted are apparently given on the assumption that they are necessary to overcome shortcomings on the part of the foundryman or his equipment rather than that the design may have been fundamentally unsound.

For the purpose of this discussion, we will concede the accuracy of the statement made by Captain Shane to the effect that " with few exceptions, European foundries make much better castings than do those in America." A little further analysis of the situation may indicate some reasons for this alleged difference. It has been my privilege to study very carefully quite a number of photographs and sketches of castings in various stages of completion produced by one of the largest steel foundries in Europe, which has a world wide reputation for the excellence of its product. At the same time I had the opportunity to discuss with several responsible executives of this concern the features of their engineering activities leading up to the development of such perfect castings. To be assigned the task of producing castings to designs as fundamentally sound from a production standpoint as these would, to the average American steel foundryman, represent the acme of his desires. In discussing several of these jobs in detail with our European friends, we developed the information that before the design of these castings was finally approved, numerous confer-

ences were held between the casting producer and the representatives of the ultimate consumer. In one case of a very large casting for a hydro-electric plant, these discussions involved visits by the interested parties to a foreign country, the development of plaster casts for some of the bucket forms on the huge wheels and other preliminary studies never dreamed of in a similar development in this country. It is my opinion that if an American foundryman or steel casting producer were to even suggest entering into preliminary discussion of a casting problem to such an extent, it would immediately be assumed that his proposition was actuated by ignorance of his business.

As compared with the consideration given to design problems in European practice, I have in mind the case of one important lot of steel castings for a prominent American consumer. To the best of my knowledge, the design of this entire lot of castings was completed without consultation with any practical steel foundryman or foundry engineer, and it is definitely known that the foundries which were ultimately given the orders to produce the castings were not consulted. In this case it was the intention to consult the foundries regarding the methods which they desired followed in producing the patterns, but on account of the delays encountered in design, it was necessary to expedite pattern production and this consultation was overlooked. To expedite pattern production for this particular lot of castings, the pattern work was divided up among several pattern shops, none of which were specialists on steel foundry production but were quite proficient on non-ferrous metals and iron. The patterns produced on this particular order were accepted by the foundrymen who did the best that was possible with the facilities at hand. The difficulties encountered due to defects which were developed on machining and failure of some of the castings in service were conceded by individuals not fully familiar with all of the circumstances as indicative of poor foundry performance. With all the facts before us, it is quite evident that much remains to be done, both by consumer and producer to correct such a situation.

Dr. Canfield's remarks on the Quebec bridge failure are quite interesting. While it is an undisputed fact that the failure originated in one of the rocker castings and that the final erection followed the original general scheme, we should not lose sight of the

fact that the design of cast steel supporting shoes originally used was abandoned and wrought steel keys of fundamentally different design were substituted for the final erection. It is generally conceded that the original design involving an assembly of cruciform castings was unsatisfactory. On the other hand, it has not been proven that defects existed in any of these castings.

Fortunately, we have in this country instances where excellent performance in the production of high quality castings has resulted from very close cooperation between designers and foundrymen. There are outstanding instances of this character, notable among which we might mention the foundry operated by the Navy Department, bureau of Ordnance, at the Naval Gun Factory where the close cooperative work between the designers, foundrymen and pattern makers has made possible the development of light weight steel castings for the ordnance mounts for Naval cruisers that I think can be compared favorably with any castings produced anywhere.

Other recent developments indicate a growing tendency toward closer cooperation between designers and foundrymen. In another contribution to this issue reference is made to Rules for Limitation of Weight in the Manufacture of Steel Castings, recently issued by one of our leading locomotive manufacturers. It is interesting to note under discussion of the engineer's duties, the following:

1. Engineer shall familiarize himself with steel foundry practice, and use that knowledge in the design and weight estimating of his product.
2. He shall always be in close touch with the pattern shop and shall prescribe such rules as would preserve the dimensional accuracies of his design.
3. He shall be familiar with pattern shop practice when limited weight castings are specified and his drawings shall show the allowable changes the pattern maker may make in order to keep the castings within the specifications.
4. He shall call the steel founder into consultation when castings of new or complicated design are under consideration.

Our remarks regarding the importance of studying design by foundry engineers is substantiated by Captain Shane's observation of the practices in Europe. The practice referred to in this report of having the pattern manufactured by the casting producer is considered quite sound and, in my opinion, is a big improvement over the conventional practice in this country. The third advantage of this procedure as quoted by Captain Shane is outstandingly important in that basic features of design which are impractical will be discovered and reported without having to find it out through a lot of expensive losses. The ample provision of feeding heads and the intelligent application of chills are far more readily accomplished where the drawing is interpreted and the pattern manufactured under the supervision of the casting manufacturer instead of by the customer's pattern maker who is, in many cases, not sufficiently familiar with the facilities of the foundry involved to intelligently plan the pattern.

The references to important operations of melting, sand control, heat treatment and inspection, contained in these papers, are very interesting and merit considerable discussion.

MELTING.

Much could be written, pro and con, on the process or method for melting steel. Details of operations will vary greatly, as they should, between different plants, depending on local conditions such as design of furnaces, character of fuel or melting power available, character of raw materials, etc. The duration of the melting cycle is no criterion as to quality of the steel. We know of plants operating on short melt time cycles by the use of very high quality raw materials that produce steel equally satisfactory for the purpose intended as the products of other plants operating on the long time cycle.

The object of any steel manufacturing process is to carry the raw materials through the successive stages of the melting and refining operations so as to finish the melt in a properly refined and deoxidized condition and of the proper temperature for the work at hand. The details of these operations must necessarily vary and can only be successfully accomplished under scientific control. Practically without exception the melting operations in American steel foundries are under scientific control.

Based on the examination of innumerable samples of steels from foreign sources, I have no apology to offer for our American steel making practice nor the quality of our product. While in some cases European steel makers may go to greater pains in getting historical data on the quality of finished products and may have more of this type of data than some American plants, I do not believe that any European plant exercises a more detailed scientific control of their melting operation through quick tests of metal, slag, etc., and the control of furnace operating conditions than is practiced among the best steel makers in this country.

The American steel casting industry is in many instances seriously handicapped by the requirements of rule of thumb specifications covering physical characteristics which in many cases fail to recognize the difference between castings of heavy and light section or the nature of service stresses to which the castings will be subjected. This, in many cases, necessitates subordinating fluidity and casting properties to a factor of minor consideration, and greatly restricts the foundry metallurgist in his selection of the most suitable type and composition of steel for producing a sound, finished casting. From my limited knowledge of European products, I am inclined to believe that foreign casting manufacturers have much greater latitude in this respect. It is hoped that the research program being undertaken by the Naval Research Laboratory on fluidity and other properties of molten and solidifying steels will clear up some of these controversial issues. This would be of great value to the foundry industry.

SANDS.

On account of geographical distribution of American steel casting plants, the question of foundry sand is largely a local issue, the sand practice in any given locality being greatly dependent on the character of the raw material deposits which are available within a reasonably short hauling distance.

Equally satisfactory results are being obtained in different plants using synthetic sand mixtures and with properly selected natural bonded sand. While Europe may have some advantages of better natural supplies of foundry sand, the rapid advance which we are making in this country in sand control under the

sponsorship of the American Foundrymen's Association will probably result, within a few years, in American sand practice equal to any in the world.

Captain Shane's description of the use of the specially prepared foundry refractory "Chamotte" as used in various foundries in Europe is extremely interesting and I am sure that the American casting industry will follow with great interest the series of experiments with the use of "Chamotte," which it is understood will be undertaken in one of the Government Navy Yard foundries.

The mold and core bonding materials described by Captain Shane are quite similar to bonding materials used in this country under other names. To meet many specialty foundry requirements in this country, both on green sand and dry sand molding, and to accommodate the various classes of sand used in different locations, American foundry practice has a very large variety of different classes of specially prepared bonding materials to choose from.

HEAT TREATMENT.

We fully agree that all castings should be given heat treatment, at least sufficient to remove casting strains. In heat treatment, as in melting, we cannot set down standard methods of procedure covering temperatures, duration of heating, cooling, etc., which are applicable to various types and weights of castings.

We cannot agree with the statement that rate of cooling is more important than rate of heating, nor can we concede that a slow furnace cooling operation is the only proper method for heat treating of all types of steel castings. While it might be suicidal to treat by drastic cooling or even normalizing a large casting having great variations in section, the same treatment operations may be the very best that can be selected for a small casting of the same composition. With the increasing use of alloy steel castings, elaborate heat treatment processes adapted to the particular job at hand are being developed in this country. These treatment operations are subject to the same scientific control that is exercised on other alloy steel heat treatment problems. The impetus furnished in America by the demand for special castings in connection with high speed, light traction equipment, motor trucks, etc., has probably resulted in a greater development of special

heat treatment technique in America than exists in Europe. Much of this present day development is in connection with quantity production of castings of practically similar size and design, but there is no reason why with the intelligent application of engineering knowledge these developments cannot be carried into the field of jobbing castings to the same extent as has already been accomplished in the American forging industry.

There has been considerable discussion during the last few years on non-destructive testing of castings by the use of X-ray or Gamma Ray and the development of these methods is being followed with great interest by the steel casting industry. With intelligent interpretation of the results of this method of examination, both consumers and producers of castings will be benefitted. The difficulty to be apprehended with this method of testing is that of arriving at a proper and intelligent interpretation of the findings. To be of any value, the findings of laboratory workers should be discussed with those having a full knowledge of the methods of production and considered on the basis of whether the apparent defects are those which are inherent to the particular design or unusual and not to be expected. Properly utilized, these inspection methods will be useful, not only in discovering dangerous defects but also by assisting the designing engineer in the perfection of casting design. The particular field for Gamma Ray or X-ray inspection is on large castings where it is impractical to cut the casting into sections for inspection. In the case of small castings which are produced in large quantities of the same design, the sectioning of a typical casting to determine the presence of internal defects will probably continue to be the most accurate and satisfactory method for determining soundness.

The research program being undertaken by the Naval Research Laboratory should be of great interest and value, primarily to American industry and also to the Navy, particularly if this field of research is confined to the determination of fundamentals on the properties of liquid and solidifying steels, the influence of changing shapes on the soundness of cast steel sections, and other similar data which can be utilized by the foundry engineers and designing engineers in arriving at improved practice. Our national foundry societies dealing with various phases of the industry are

covering that portion of the field applying to practical operating conditions in a rather complete manner, and interchange of ideas covering practical problems is probably freer in America today than ever before. Very little constructive research work has been previously undertaken on the phases of the problem contemplated by the research program of the Naval Research Laboratory and if this program is carried to completion along the lines as now planned, the result will be to furnish valuable data in a much neglected field.

THE PURCHASE OF STEEL CASTINGS FOR NAVAL USE.

By Jerome Strauss.*

A request for constructive criticism of a system of design, purchase and inspection (for that is truly the scope of a Navy Department Specification) in which one has in previous years taken pride because of partial responsibility for its development, establishes a task and a degree of gratification. And having had an opportunity to view the problem clearly from both sides, one should be able to bridge any gap between them more successfully.

The statement of the problem is simple, its solution not quite so obvious. Basically, a specification is merely the buyer's detailed expression of that which he desires the manufacturer to provide. Initially it is a description of an article and perhaps also its method of preparation, ultimately often a source of bitter disagreement and a serious loss to one or both parties. Experience has shown these undesirable occurrences to result from errors of both sides—the establishment of impossible auxiliary requirements (the design in the case of castings) as well as the failure of the supplier to fully read and absorb all the requirements or his assumption that they may be waived. But to return to the immediate problem, it is clear that the Navy desires (1) castings of the form described in the individual blueprint, homogeneous and of uniform density throughout (2) castings possessed of the best mechanical properties available and in any case suited to the design and to the service to be rendered.

Failure to attain the first objective has been due to many causes. Foundries have not always had their present coordinated staffs, their metallurgical control of melting practices and their engineering control of pattern and mold making. They have not always followed the practice of cutting up the first small castings of a lot in order to be assured of correct gating, heading, etc., nor has

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radiographic equipment been available whereby large castings might be studied individually and simultaneously inspected. They have likewise been under pressure, at times, from overemphasis of the need for making money for their owners, resulting in initial small savings and ultimate larger losses. It is obviously unwise in the case, for example, of a large gun slide carrying heavy trunnions to use heads on these trunnions just slightly larger than the trunnions themselves, when fifty per cent increase in section will insure results. The mold and casting are costly, the risk is great and limitations such as flask dimensions or a few extra pounds of metal are foolhardy. Furthermore, few foundries are financially able to support fundamental research to develop principles upon which their operations may be based. A few, forming parts of larger organizations, have put some effort into these problems; groups of smaller foundries have endeavored with more or less success to undertake these tasks cooperatively. But these efforts are of only a few years standing (it should be appreciated that sound metallurgical development is not instantaneous) and their more fundamental work, in times like the present, must often be sacrificed to more commercial details upon which their mere existence depends.

On the other hand, the designer has had his full share of the responsibility. Insistence upon forms that offered no opportunity for fully meeting the requirement under discussion, have been frequent but are fortunately decreasing. Huge changes of section thickness over extremely short distances and heavy masses impossible to feed during solidification, are among the offenses. More effective use could be made in some instances of assembled structures of cast parts only, or of cast with wrought members, joined by bolting or riveting or welding.* Higher initial cost, if it be higher in any instance, would often be outweighed by the loss of a large complex casting or the delay to an entire program resulting from such loss.

Toward the solution of these difficulties, the work now under way at the Naval Research Laboratory and, not only upon steels but on other alloys, at the Bureau of Standards and several indus-

* This still seems to be a horrible word to many, yet machine parts, ships, buildings are being successfully produced by modern welding technique and equally successfully used; moreover, the Navy itself is developing much of our ranking information on the process and its application.

trial research laboratories, should contribute greatly. The data ultimately secured must serve a dual purpose—not only to inform the manufacturer of the limitations of his metals and his methods but to impress upon those responsible for design the boundaries within which they must confine their desires when demanding a casting of unvarying density and absence of cavities and cracks. But this knowledge can not be developed in a matter of months. And until it is at hand there must be an avoidance of questionable practices in design and of questionable methods on the foundry floor. Further assistance should be provided by specification improvement—cutting of heads and gates from high strength or high-carbon castings should be performed only while castings are hot or after the first heat treatment where more than one is applied. Inspection methods should be such that the questionable value of visual inspection of fractured lugs need be resorted to only with small castings and separately-poured test bars. As the hammering of a suspended casting has been proven only partly effective in detecting serious unsoundness, it must be supplemented by other methods. Radiography has its place but because of cost, inconvenience and lack of general availability of equipment, might well be aided by provision for the dissection of preliminary castings. Such methods can not conveniently be insisted upon in a general specification but the requirement of soundness without discussion of methods for its assurance seems ineffective also. The reference to metallographic examination in its present form seems futile. These might all be combined into a usable and understandable description of inspection procedure.

Requirement (2) now invites attention to a somewhat different phase of the problem. In earlier years the demands of Naval construction have always been a primary force in the direction of metallurgical advances and it would be regrettable now were that position to be sacrificed in any degree. But one limitation of the present specification for steel castings is a stumbling block to progress—namely, the severe restraint upon the form of heat treatment. Resistance to deformation and rupture under suddenly applied loads is of primary importance in many steel castings for Naval use; second in importance is high elastic strength. Yet of all the types of heat treatment commonly applied, full annealing

as now specified for all grades, is productive of minimum values of these two properties. Normalizing, on the other hand, *combined with suitably selected composition*, may be applied to produce increase in yield point, and hence increase in safety factor or in usable design strength, ranging from 10 to 30 per cent accompanied by a two to five-fold increase in impact strength, *without loss of ductility as measured by either the tension test or the bend test.*

To those who may criticize the suggestion of rapid cooling in the heat treatment of castings on the ground of danger of cracking, it may be remarked, first that drastic cooling or quenching as in a liquid medium is not recommended although such procedure is applicable to a number of Navy castings and is practiced to a large extent commercially on simple forms. Second, that cracking of steel castings results either from high cooling rate or restraint of free contraction during original cooling from the molten state, thermal or mechanical shock after this cooling and before reheating, or too rapid reheating for heat treatment or other purposes, and not to air cooling from the heat treatment temperature. And third, that normalizing has for quite a number of years been practiced with perfect success by most American steel founders. It is neither dangerous nor new.

A few test results will serve to illustrate some of the above statements. In the accompanying tabulation of tests of steel castings, the first set of values are of annealed material complying in all respects with grade "C" of the Navy specification. Similarly Tests 2 and 3 are representative results on annealed castings meeting tension test limits set for grade "A" carbon steel, while Test 4 is characteristic of the annealed nickel steel castings furnished to meet grade "F." These may be compared with Tests 5, 6, 8 and 9 indicative of the benefits to be derived from the application of normalizing treatments to suitably balanced steel compositions. The toughness indicated by the high reduction of area and impact resistance combined with the greatly increased useful strength represented in the yield point values are worthy of serious consideration. The tests thus far mentioned were taken from separately-poured test bars; that they are not, however, unrepresentative is shown by Test 7, removed after heat treatment from a

TABLE I

PROPERTIES OF SOME STEEL CASTINGS.

Test No.	Composition C	Si	Mn	Ni	V	Yield Pt. Lb./Sq. In.	Tens. Str. Lb./Sq. In.	Elongation per cent in 2 In.	Reduction of Area per cent	Izod Impact Ft. Lb.
1	.30	.27	.49	.....	.....	35,750	71,500	31.5	46.6	14.3
2	.28	.45	.73	.....	.....	44,750	85,000	28.0	45.8	20.3
3	.39	.31	.68	.....	.....	43,250	88,300	24.0	36.6	8.8
4	.35	.32	.66	3.45	.....	59,450	89,800	24.0	48.4	26.3
5	.30	.42	1.60	.....	.10	78,000	102,200	29.0	61.0	60.0
6	.35	.42	1.39	.....	.10	74,600	100,000	28.5	58.0	53.0
7	.30	.38	1.65	.....	.11	68,500	103,250	27.0	61.8	48.0
8	.28	.24	1.00	1.59	.10	69,900	91,200	28.5	59.4	74.3
9	.32	.44	1.11	1.66	.10	74,730	102,800	29.0	57.7	38.5

10,000 pound casting having a maximum section of 14 inches. All of these normalized steels will give a bend test of 180 degrees on a standard test bar.

It is not the intention to declare that all castings may satisfactorily be subjected to a normalizing treatment. Cracking, however, need not be feared from this method of processing. Some extremely sensitive castings of very intricate form and unbalanced section may perhaps not be so treated for fear of distortion but these are believed to be very few in number. In some instances it seems likely that re-design with the object of utilizing the benefits of more rapid cooling in heat treatment, would be productive of ultimate economy. In other cases, no doubt, as in the largest gun yokes, sections are too heavy to permit full benefit from air cooling. Only in the latter cases and in those where rigidity alone (due to the fairly constant elastic modulus of steel) dictates design is it not possible to make these higher strengths available and thereby effect weight savings that are so valuable in ships of limited displacement.

Of course, improved mechanical properties that permit increased design stress with simultaneous added insurance against rupture by sudden overloading, cannot be of importance in the presence of unsoundness resulting from faulty design or faulty manufacture. But advances in our knowledge of the behavior of liquid metal during solidification combined with a broader use of the dissecting and radiographic methods are rapidly reducing such occurrences. There would appear to be therefore an immediate opportunity for combining with improved design, manufacture and inspection, the application of modern high strength steel now quite generally avalable. Grades C, D and a " Super F" might then ably supply all needs.

INFLUENCE OF DESIGN ON STEEL CASTINGS.

By J. E. Crown.*

The influence of design on the quality and cost of steel castings is of utmost importance to the engineer and he should have an understanding of the fundamental principles involved in the casting of metals as an essential requisite for a good designer.

Unfortunately many present day designs for steel castings reflect the conventional designs of the cast-iron era, especially when direct substitution of cast steel for cast-iron has been made for increased strength.

Cast-iron as compared to cast steel has greater fluidity, pours at a lower temperature, sets at a slower rate, has less shrinkage, less contraction and is less severe on a sand mold.

Cast steel is usually poured at a minimum of 2800 degrees F., the temperature varying with the size and cross-section of the casting. Molten steel starts losing heat as soon as the metal is tapped from the furnace, but the most drastic loss is when the metal comes in contact with the sand mold. As soon as a mold is poured a solidified crystalline shell is formed conforming to the contour of the mold and solidification continues from the outside toward interior until the entire casting is solid. During this period of solidification shrinkage takes place, the lighter section being "fed" from the heavier sections, and at the heaviest section provision must be made in the mold to supply a column of metal known as a shrinkhead to feed metal to this last section to prevent internal shrinkage.

Figure 1 is a simple illustration of this phenomena.

Were it possible for the engineer to so design that shrinkage could be controlled as illustrated in Figure 1, which is an ideal condition, there would be no excuse for the production of a casting with internal shrinkage or "inherent" defects. From a design standpoint that is impracticable, castings must be designed with

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ununiform crosssection, protruding lugs and bosses and heavy sections created at the juncture of reinforcing ribs and the foundry must resort to artificial means of controlling the rate of solidifying by the use of interior and exterior chills, by radiation of heat from the casting and by the proper location of gates and risers.

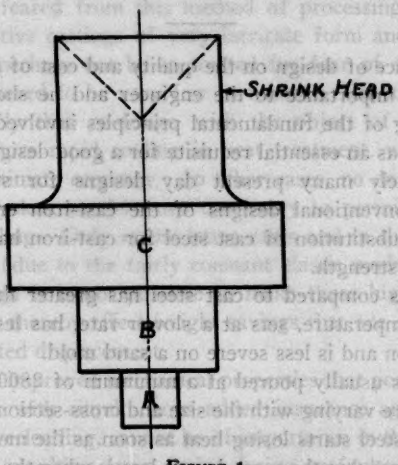

FIGURE 1.

Immediately following this shrinkage period, the steel, then in a plastic state, slightly expands then contraction starts, which continues until the casting reaches room temperature. To permit unrestricted contraction a mold or core should be strong enough to withstand the pouring of the metal only, and then collapse through the medium of hollow or coke filled interiors, removable flask sections, weak backing sand and release of holding down clamps and bolts.

Deep flanges, long protruding lugs, cored openings, irregular shapes and numerous shrink heads required by design, retard the normal contraction, while drastic change in cross-section causes a difference in rate of contraction of different parts of the same casting. Each of these tend to create cracks at the restricted section.

When metal solidifies, crystals are formed at right angles to the cooling surface, hence sharp square corners as illustrated in Fig-

ure 2 are weak, due to conflict between crystals of adjacent sides. A liberal corner radius creates an interlocking crystal between these sides.

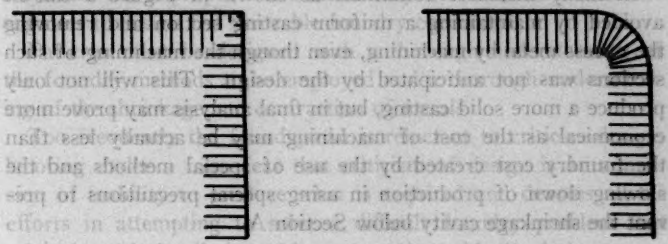

FIGURE 2.

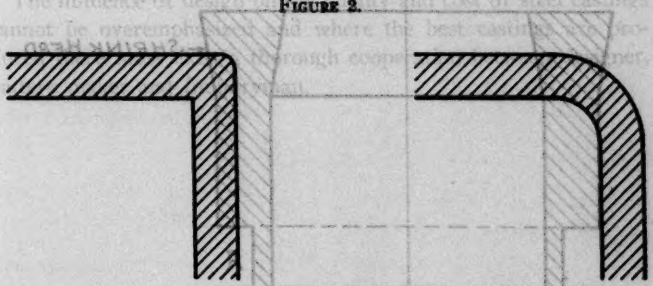

FIGURE 3.

A sharp internal corner as shown in Figure 3 not only gives poor crystalline structure, but the sand required to form the corner is small in cross-section and radiates heat so slowly that a "hot spot" is created. A liberal fillet permits greater heat radiation and improves crystalline structure.

Quite frequently the design of the finished product may be entirely uniform in metal thickness, yet parts of the casting are to be machined while others are not and the increase in pattern size to allow metal for machining creates an ununiform cross-section at pouring and results in defective castings.

Where change in cross-section is necessary in design, it is essential that, where practical, one thickness be blended into the other and sudden changes avoided. "Bottle necking" should be

especially avoided as it is obvious that it is impossible to properly "feed" a 3-inch section through a 2-inch section as the latter will be solid before shrinkage of the former has been completed.

In many instances conditions as shown in Figure 4 can be avoided by maintaining a uniform casting section and removing the excess metal by machining, even though the machining of such sections was not anticipated by the design. This will not only produce a more solid casting, but in final analysis may prove more economical as the cost of machining may be actually less than the foundry cost created by the use of special methods and the slowing down of production in using special precautions to prevent the shrinkage cavity below Section A.

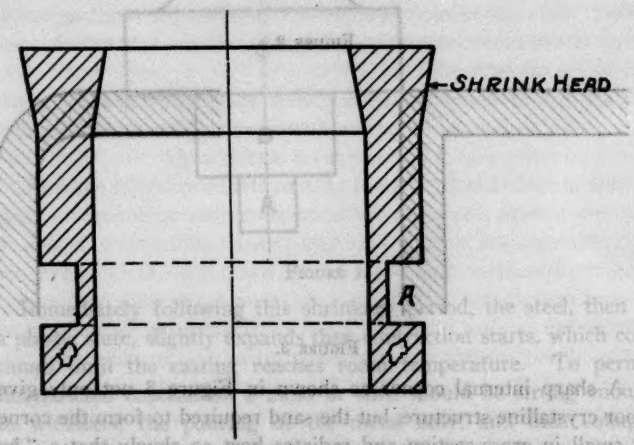

FIGURE 4.

Double T sections formed by ribbing, causing a concentration of metal and requiring special shrinkheads or chills to prevent shrinkage cavities, may often be avoided by staggering of the supporting ribs.

Metallurgical progress has been rapid in the steel industry, new alloys have been developed, physical properties studied, melting and heat treating technique improved, and scientific inspection methods devised. The designer would profit by knowledge of these developments and an understanding of the foundry charac-

teristics of the various alloys. This would result in a more intelligent selection of materials and a higher quality product.

A pattern for a given design may often be constructed in several ways and the improper construction may defeat all efforts of the engineer to design for favorable foundry conditions.

Patterns must be designed with a thorough understanding of the foundry methods to be employed and a thorough understanding of the shrinkage and contraction of metals.

Too frequently the foundryman is reluctant to criticize design, laboring under a false fear that criticism of design is an admission of inability to produce what is required and devotes all his efforts in attempting to solve a difficult foundry problem that might be entirely eliminated by cooperation with the designer.

The influence of design on the quality and cost of steel castings cannot be overemphasized and where the best castings are produced there must exist a thorough cooperation between designer, pattern maker and foundryman.

NOTES.

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AIRCRAFT IN THE NAVY.
The Engineer, December 2, 1932.

CONDENSATE AND FEED PUMPS.
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WEIGHT LIMITATION IN MANUFACTURE OF STEEL CASTINGS—RULES OF PROCEDURE.

By Captain R. C. Davis, U. S. Navy, Member.

The need for the elimination of excess weights in ship construction has been recognized for many years by the shipbuilding industry as contributing to better ship performance, economy of fuel and increased cargo carrying capacity.

The Washington and London Conferences on the limitation of armaments have merely accentuated the need for the elimination of superfluous weights, consistent with the safety requirements, in both hull and ship machinery designs. When they agreed to tonnage limitation by ship categories, the treaty makers gave little thought, if any, to the effect of their decision on the Naval architect or the Naval engineer. From the viewpoint of improved machinery design, installation arrangements, space requirements, and development of new construction methods, the conference agreements are blessings in disguise. In order to permit of the installation of the maximum propulsive power and armament in a ship of limited tonnage, those agreements placed a high premium on the elimination of unnecessary weight and the simplification of both ship and machinery designs. It is quite obvious that the steel foundries are affected and they must meet the changed conditions. What is desired of the founder is hearty cooperation with the view of meeting the requirements as to weight and dimensional tolerances when design calculations show that they may be reduced safely.

While much improvement in foundry technique remains to be done by the industry, it is not the intent to convey the thought that the foundry is the only place where the elimination of superfluous weight may be accomplished. In the case of ship construction, the decisions of the designing architect and the engineer have far greater influence on the elimination of excessive weights. Their responsibilities involve the correct preparation of designs, strength calculations, methods of construction and selection of materials for each particular structure or system built into the ship. This requires not only complete knowledge of the design and its purpose but also of the strength and reliability of materials capable of being used therefor. From the viewpoint of weight saving, the designer must consider the function which each part must serve, the strength or load requirements and the type of stress to which it may be subjected. In many cases rigidity, or stiffness, is of as much importance as strength, in which event it would not be good engineering practice to reduce the thickness of sections below approved standards.

Regarding highly stressed members of steel structures, where the modulus of elasticity for the particular grade of steel is the controlling factor in the stress, the thickness of section can not be reduced beyond that required by acceptable factors of safety.

It is fair to assume that, for a given steel, the modulus of elasticity values are not influenced by special heat treatment or working. The above is mentioned as one of the considerations of the designer, since some rather extravagant statements have been published quite recently to the effect that the modulus of elasticity values may be improved considerably through special heat treatment. Research and tests disprove this and also that no appreciable improvement in those values can be obtained except through changing the chemical composition of the steel. Therefore, when the modulus of elasticity is the controlling factor, the designer must not be misled by promises of increased values through special heat treatment.

Besides the shipbuilding industry, there are several large industries wherein the elimination of superfluous weight is more or less mandatory. Prominent among them are the railroad and aviation industries.

The demands for increased power within a limited weight in steam locomotive engines, and the necessity for not exceeding such weight on their tracks, trestles and bridges, is required by certain railroad companies. This has made it mandatory for the engine builder, particularly in the case of weight penalty contracts, to demand and to expect the steel foundries to keep within the dimensional tolerances and weights given on the approved plans. There are competitive factors also, such as the increased use of Diesel electric or other types of locomotives and the employment of electric welding and use of rolled steel plate construction where permitted by the design. Even with the existence of such competitive factors, there always will be a demand for sound steel castings that meet the physical requirements and that are within the specified weight limitation and dimensional tolerances. This calls for real cooperative effort on the part of the design engineer, the patternmaker and the founder, including proper organization of the foundry under engineering management as suggested in Captain Shane's article appearing elsewhere in this issue. That one of the prominent American locomotive engine builders is keenly alive to the foregoing conditions is evidenced by the rules of procedure for the successful limitation of weight in the manufacture of steel castings adopted by that builder. These rules were prepared by one of their representatives who was identified for many years with foundries and their construction and operation. They are common sense rules founded in the school of experience and are reported to have been observed quite successfully for the past two years in the three foundries that employ them. Other industries could well emulate them by direct application or with modifications. Through the courtesy of Mr. John P. Sykes, Manager of Inspection and Field Service, the rules of procedure adopted by the Baldwin Locomotive Works are presented here as of interest in connection with the other articles on Steel Castings in this issue of the JOURNAL.

DISCUSSION.

No rules of procedure in the manufacture of steel castings can be effective unless all the parties in interest thoroughly understand their purport and the reasons which lead to their adoption.

THE ENGINEER.

The engineer especially should have a keen interest in the results of the procedures of production and in the dimensional tolerances determined upon. He should be reasonably familiar with steel foundry practice and should use that knowledge in the design of the product.

As an instance of this need, the case of steam pipes may be cited. These pipes at best are extremely difficult to produce even approximately to card sizes. By reason of their irregular shape, and the difficulty of holding the cores in the proper position, the founder rarely can keep the sections within the tolerances. When the engineer designs the pipe with $\frac{5}{8}$-inch walls, the founder knows for a certainty that when he sets $\frac{5}{8}$ inch as an outside thickness, some part of the pipe will be below that figure. In fact he knows that he cannot procure a satisfactory pipe of that thickness. He will probably demand a $\frac{3}{4}$-inch thickness and will use that figure as his minimum section.

When these and many other steel foundry problems are taken into consideration by the engineer, much of the erecting troubles and casting overweight will be avoided.

The engineer should be in a position to consult the steel founder as to the practicability of casting shapes of new and novel design.

The engineer should be deeply concerned with dimensional tolerances and the influence they may have on his estimated weights. He should endeavor to assist the patternmaker and the steel founder in keeping the weights within his estimate by marking on the drawing his estimate of what the weight of the casting should be.

He should be fully alive to the fact that it is impossible to make a casting to the precise dimensions of the drawing but that it is entirely feasible to control to a great extent the variations the casting may exhibit. Once the essential tolerances are understood and established, the added weight due to these tolerances should be figured in the total estimated weight of the casting. The casting may and at times will, weigh less than the estimated weight but so long as it is within the given dimensional tolerances, it should be satisfactory. The probabilities are that the actual weight will be consistently greater than the estimated weight and to some extent the estimate will not agree with the actual weight. The difference, however, will not be especially marked.

When a limited weight casting or set of castings is specified the patternmaker changes his usual procedure for the construction of the pattern. Habit is very strong and unless he is constantly reminded, he is apt to slip into his accustomed groove. It is not that the patternmaker figures on the weight while making the pattern but the fact that the designer has taken the trouble to estimate the weight and place it on the drawing, is a constant reminder to him.

To the founder, the presence of the estimated weight of the casting on the drawing is a mark within which he must keep. When the first casting shows a marked overweight, he must go back over his work and correct his procedure. There should be no excuse for a large or small number of overweight castings.

There are cases where, in the opinion of the founder, a section may be too light or where such light sections would promote cracks and strains. These are questions of design and should be settled by the designer in consultation with the founder.

No change or addition to a pattern affecting the design should be made without the approval of the engineering department. On the other hand the department should recognize the necessity of providing sufficient metal to insure ample sections and to secure a clean machined surface at points where variable shrinkage occurs.

Much has been said about the evils of "rapping" and its influence on the overweight. Good foundry practice with properly drafted patterns adds but little weight from rapping and this weight must be included in the engineer's calculations. The evil of excessive pattern rapping would be controlled largely by dimensional tolerances and weight tolerances.

It is logical that the tolerance should be placed on the limits of overall and sectional dimensions rather than on the weight of the casting but in working to such a tolerance, a certain amount of overweight is likely to follow.

No steel founder can guarantee a 5 per cent weight tolerance and at the same time guarantee a sectional thickness of 1/16 inch plus or minus coupled with a ¼-inch overall tolerance on a complicated casting.

At best the steel founder can meet his specifications only by having good equipment in first-class condition and then by the exercise of constant care and attention. However, the engineer has the right to expect those foundry conditions and just that care and attention to his work.

THE PATTERNMAKER.

Upon the patternmaker rests the responsibility of making such shrinkage and draft allowances as will produce a casting which will satisfy the demands of the shop organization for finish and of the engineer for soundness and strength. He has no tolerances in his pattern other than his draft allowance and the degree of accuracy customary in wood work of this character. The pattern dimensions must be reasonably exact when scaled with the shrinkage rule.

No two steel foundries have the same shrinkage on large and complicated castings. Nor do any two of them adopt precisely the same shrinkage allowance for such castings.

Where large castings of new and novel design are to be made, there may be two and sometimes three distinct shrinkage allowances on one casting. The first casting from such a pattern is always a matter of experiment, judgment and a measure of guess. The difference of shrinkage allowance gives rise to the demand for added metal where the result is in doubt or where a machined surface is specified.

Many of the machine shop requirements for additions to the pattern are for the purpose of insuring a clean machined surface. If the shrinkage in a steel casting were consistent, *i.e.*: if the casting shrunk evenly at every point, there would be no necessity for this extra allowance but, unfortunately, this is not the case.

There are points in a locomotive cylinder where the cores will not permit any shrinkage and none is allowed, and there are points where a fixed allowance over the usual 3/16 inch to the foot must be given in order to bring the casting to the approximate dimensions.

There can be no fixed rule governing shrinkage allowance.—This must be left largely to the judgment of the patternmaker and the individual practices of the foundry in which the casting is to be made.

It has been the shop practice to make additions to the pattern at points where there is finish and it is the opinion that such practices are legitimate. This especially refers to backing up the pattern at those points.

However, the foundry sometimes calls for additions to make the molding easier or guard against variable shrinkage or inaccuracies of core setting. These practices are not legitimate and should be prohibited except in rare cases. The remedy lies in accurate pattern making strictly in accordance with sound foundry practice.

Draft as ordinarily applied slightly increases the weight of the casting. When a limited weight casting is specified, the draft is made to average the dimension, one-half of the draft being below the dimension and one-half over. A one-inch rib is 15/16 inch at the top and 1-1/16 inches at the bottom. This principle is carried out in the entire pattern and tends to keep down the surplus weight. The patternmaker has control of this feature and, with the approval of the engineering department, should apply it to all unmachined surfaces of patterns where there is weight limitation.

THE STEEL FOUNDRY.

A steel foundry with first-class equipment has very little excuse for castings abnormally overweight or with the sections much thicker than the allowable tolerance. If the flasks are substantially built with the joints machined, if they are equipped with ground steel pins fitted to steel bushings, and if the core plates are of ample thickness for stiffness and with a true planed surface, the first essentials of good foundry practice are effected.

But if the flasks are warped from heat and the joints are not true or the flask pins are loosely fitted, invariably there will be a substantial overweight

in the casting. If the core plates are light, they will warp in the baking and cracked or distorted cores will be the result.

All these make for overweight and oversize sections. Such a foundry cannot meet consistently a reasonable tolerance and is prone to demand such sections which will meet their foundry conditions.

If a foundry practices casting in cores, their success depends on their ability to produce correct cores and the means they use to hold the cores firmly in the proper position while casting. Casting in cores demands a higher degree of skill in meeting the casting requirements from the first step in designing and making the cores to the last step in closing and pouring the mold. But once the work is properly performed, the result comes closer to the drawing than does the dry sand or green sand process.

The greatest cause for overweight lies in the lifting of the cope or cover core due to insufficient clamping or the use of too much soft clay between the cope and the drag to equalize the inequalities of the flask joints. Overthick flanges and heavy sections are the direct result of these conditions. They are easily recognized in a casting and the founder should be penalized when they occur.

Tolerances.—Recognizing that it is impossible for a steel foundry to make a casting that conforms exactly to the drawing or to the pattern, a dimensional tolerance should be determined upon. It is entirely logical that this tolerance should be placed on the limits of overall and sectional dimensions rather than on the weight of the casting. But in allowing such a tolerance, an added weight must be taken into consideration.

No steel founder can guarantee a 5 per cent tolerance in the weight of a large and complicated casting and at the same time guarantee a sectional thickness of 1/16 inch plus or minus. An overall dimensional tolerance of ¼ inch on such a casting with 1/16 inch plus or minus on the sections could be effected only by a foundry with high class equipment and could be maintained only with the exercise of the most constant care and attention. However, the shop and the engineer have a right to expect these foundry conditions and attention to the work.

The tolerances should be set so that a steel foundry with high class equipment and good workmanship could turn out satisfactory castings and with no more than the normal percentage of loss.

The foundry should eliminate those shop practices which increase the weight of the casting.

The foundry should recognize that the main cause of overweight of castings is not in rapping the patterns and core boxes but in the cope or cover cores lifting under the tremendous pressure, and in recognizing this, should take energetic measures to avoid this defect in its equipment.

The inspection department should, in consultation with the engineer, set the tolerances.

The inspection department should determine the corrections, if any, allowed to be made upon castings which exceed the determined tolerances.

The inspection department should demand strict adherence to the determined tolerances.

RULES OF PROCEDURE TO BE FOLLOWED IN THE MANUFACTURE OF STEEL CASTINGS.

THE ENGINEER.

1. The engineer shall familiarize himself with steel foundry practice and use that knowledge in the design and weight estimating of his product.

2. He shall always be in close touch with the pattern shop and shall prescribe such rules as would preserve the dimensional accuracies of his design.

3. He shall be familiar with the pattern shop practices when limited weight castings are specified and his drawing shall show the allowable changes the patternmaker may make in order to keep the casting within the specification.

4. He shall call the steel founder into consultation when castings of new or complicated design are under consideration.

5. He shall have a thorough knowledge of the tolerances already in existence and shall be controlled by them in his designs and weight estimates whenever possible.

6. He shall use these tolerances in all his estimates of casting weights and shall assist the patternmaker and steel founder wherever possible in keeping the weights within his estimate by marking on the drawing his estimate of what the weght of the casting should be.

7. In furtherance of this, the following rule shall be adopted:

8. The drawings for all steel castings must have the following legend stamped on the original tracing:

"The estimated weight of this
Casting is.....pounds.
It will be subject to rejection if it
weighs less than.....pounds
or more than.....pounds."

(If over the maximum, the weight may be properly corrected to within the specified limit.)

TOLERANCES.

1. It is recognized that a certain amount of tolerance must be allowed the steel founder in the weights of castings as shipped, these tolerances to apply to both overall and sectional dimensions.

2. The procedure for determining when a casting is overweight shall be as follows:

3. The weight of the casting shall be estimated from the drawing by the engineer and marked on it plainly and to this weight shall be added the weight of the total allowable dimensional tolerance. Weight of casting in excess of the sum of these two shall be charged back to the founder and weight limit castings shall be subject to rejection if so overweight.

4. The weight of the tolerance shall be computed as of an average cross section of the casting in inches times the tolerance times the weight of one cubic inch of steel. The tolerance weight of the length and width shall be added together.

5. The dimensional tolerances to be allowed shall be as follows:

Overall length	Plus inch	Minus inch
Castings four feet long and under	1/8	1/16
Castings four feet to eight feet long	5/16	1/8
Castings eight feet to fifteen feet	3/8	3/8
Castings fifteen feet to thirty feet	3/4	1/2
Castings over thirty feet to fifty feet	1-1/4	3/4

6. The tolerance for width shall be the same as for length.

Sectional tolerances	Plus inch	Minus inch
Sections under ½ inch	1/32	1/32
Sections ½ inch to 1 inch	3/64	3/64
Sections 1 inch to 1½ inches	1/16	1/16
Sections 1½ inch to 3 inches	3/32	3/32
Sections over 3 inches	1/8	1/8

THE PATTERN SHOP AND PATTERNS.

1. There will be no tolerance allowed in pattern dimensions other than error created by use of shrinkage rule which shall be used for taking all measurements.

2. The drawing shall be plainly marked by the patternmaker with the amount of shrinkage allowed usually 3/16 inch to the foot. In case two or more shrinkages are allowed on the same pattern, those parts requiring more or less shrinkage than the standard shall be plainly indicated in addition to the standard shrinkage.

3. No additions to the pattern over or under the dimensions of the drawing will be permitted except where it is necessary to provide for finish on a machined surface.

4. The amount of this addition for finish must not be more than ¼ inch over the drawing dimension unless unusual conditions prevail.

5. Where limited weight castings are specified, all additions for finish must have the approval of the engineering department.

6. No additions to the pattern over the drawing dimension shall be made when that addition is designed to correct poor foundry practice or to make the molding easier.

7. No addition to the pattern over the drawing dimensions shall be made when that addition is designed to allow for warping.

8. No additions to the pattern over the drawing dimensions shall be made when that addition is designed to allow for thinness of metal caused by an excess of silica or other wash.

9. No additions to the pattern over the drawing dimension shall be made when that addition is designed as a correction for faulty shrinkage allowance.

10. Any proposed addition not covered in the above instructions must be subject to the same ruling given to specific cases.

11. Core boxes are subject to precisely the same restrictions as are the patterns.

12. No core box may be built up to secure an excess of metal except where this excess is designed to provide for finish upon a machined surface.

SHRINKAGE ALLOWANCE.

1. The patternmaker in consultation with the steel foundry executive shall be the sole judge as to the correct amount of shrinkage required.

DRAFT.

1. The patternmaker shall be the sole judge of the amount of draft necessary on any pattern.

2. On patterns for castings of limited weight, the patternmaker will divide the draft, making one-half of the total draft over the drawing dimensions

and one-half under the dimensions. When this procedure is followed, certain ribs and sections will be under size at the top and over size at the bottom. The engineering department must be advised when this occurs.

FOUNDRY PRACTICES AND FOUNDRY EQUIPMENT.

1. It is evident that the foundry must have its equipment in first-class shape if the castings are to be furnished within the given tolerances.
2. The flasks must have heavy flanges substantially ribbed and the joints must be machined. The dowel pins must be of hardened steel ground to fit hardened steel bushings accurately fitted into the flanges. The trunnions must be steel forgings cast into bosses in the body of the flask.
3. The core plates should be of cast iron and of substantial section. They must be machined true on the core bearing surface.
4. Great care must be taken to keep the flask flanges true and to this end these flanges must be made oversize to allow for subsequent machining.

LIMITED WEIGHT CASTINGS.

1. When limited weight castings are specified, the founder while closely observing the tolerances, must also remove, before shipment, all shrinkage brackets, fillet chills and raised lines intended to preserve flat surfaces. Only those brackets which are inaccessible may be left on the casting.
2. When oversize flanges or sections occur which are the result of the cope or cover core lifting, the founder shall either remove the surplus metal or be charged with the overweight plus the cost of machining it off. This will be in addition to any other excess of tolerance that may occur in other parts of the casting.
3. The founder must avoid any excessive rapping of patterns or core boxes for all castings and must pay particular attention to this rule when limited weight castings are specified.

SHOP PRACTICES.

1. Shop practices must be governed by the instructions issued under the head of "Pattern Shop and Patterns" and all pattern changes and additions must be made by the patternmaker in conformity with these instructions.
2. Shop practices that affect the weight of the casting must have the approval of the engineering department. A statement of the shop practices desired by the founder shall be furnished the engineering department together with sketches showing the changes and additions desired in the pattern. Only those changes having the approval of the engineer and the inspection department shall be permitted to be made.

INSPECTION.

1. The inspection department of the locomotive shops shall be responsible for determining conformity with the established standards and dimensional accuracy.
2. It shall provide the necessary tools, gauges and calipers to determine quickly the sectional and overall dimensions of every casting made.
3. This department will be responsible for determining any overweight and notifying the proper authorities what the back charges shall be, also for determining acceptance or rejection of all limited weight castings and all other castings received.

Through the courtesy of JOHN P. SYKES,
Manager of Inspection and Field Service.

AIRCRAFT IN THE NAVY.

That aircraft have become an essential adjunct to the Navy is a proposition which few will dispute. They are useful, if not indispensable, for many purposes, such as reconnaissance, gunnery observation, torpedo and bomb attack, anti-submarine work, and, not least, for the laying of the smoke screens which are now frequently used in fleet exercises. Although the value of aircraft for any one or all of these duties may be overrated, it is generally conceded that a fleet deficient in air power would be at a grave disadvantage if opposed to another fleet adequately provided with this auxiliary. With so much admitted, it only remains to determine the best methods of utilizing aircraft at sea. The problem is by no means solved as yet. In common with other Naval Powers, we have built a number of aircraft-carriers which fulfil the functions of floating aerodromes. The latest representatives of the type are the *Glorious*, *Courageous*, and *Furious*, of 18,000 to 19,000 tons, and an average speed of 31 knots. Each of these ships, it is stated unofficially, can accommodate about fifty machines, which are able to take off from and return to the spacious flight decks, whence they are sent below to the hangars by hydraulic lifts. A larger and slower specimen is the converted battleship *Eagle*, of 22,600 tons, while in the *Hermes*, of 10,950 tons and 25 knots speed, an attempt was made to design a ship capable of performing all the duties of the big carriers on a much reduced displacement. By all accounts, the *Hermes* has proved quite successful, and when the time arrives to build new carriers, her basic design may be adopted. But as regards the larger ships, there is, we think, ample scope for criticism. In the first place, their cost is prohibitive. According to Jane's "Fighting Ships," the *Furious* is said to have absorbed over £6,000,000, including alterations, while the *Courageous* and the *Glorious* have cost to date over £5,000,000 each. In the case of the *Eagle* it has been officially stated that up to April, 1927, a sum of £4,617,636 had been expended on her, and as she has been extensively refitted since that date it is not unreasonable to estimate the total bill at something like £5,500,000.

Now these figures would be startling at any time; viewed in the light of present economic conditions, they are particularly disconcerting. It appears that no less than £21,500,000 has been spent on four ships of the Navy which possess no direct fighting value, and whose only *raison d'être* is to carry approximately two hundred aircraft to sea. Holding no brief for the extremists who deny the value of air power in Naval operations, we are, nevertheless, driven to ask very seriously whether the Naval authorities have hitherto pursued a sound policy in the development of the Fleet Air Arm. Having ourselves witnessed aircraft evolutions with both the Home and Mediterranean Fleets, and personally cruised in more than one of the great carriers, we readily acknowledge the astounding degree of efficiency which has been attained in the handling of these ships and their brood of aeroplanes. Yet this admission does not really affect our argument. If a ship like the *Hermes*, of less than 11,000 tons, is able to fulfil the main requirements of an aircraft-carrier, was it necessary to spend £21,500,000 on converting four vessels, each of nearly double her tonnage, for the same purpose? No one will pretend that the huge expenditure thus incurred has yielded a proportionate return in fighting value. It is roughly equivalent to the collective cost of the *Nelson*, the *Rodney*, and the *Hood*, the three strongest fighting ships now afloat. Nor is her prodigious first cost the only criticism which may be legitimately directed against the large aircraft-carrier. She is, of all the units of the Navy, the most expensive to maintain in commission, the nature of her duties compelling her to steam at full power whenever aircraft operations

are in progress. Furthermore, there is the important question of vulnerability. How would these huge vessels, with their great length and towering sides, fare in action? Their armor, as shown in the textbooks, is of the scantiest; they offer an exceptionally large target to gunfire and torpedo attack, and the immense expanse of flight deck could scarcely be missed by an intrepid pilot in a hostile bomber. It is certain, too, that the large aircraft carrier would become the objective for every method of attack, since the destruction or disablement of such a ship would gravely impair the vision, and hence the strategic mobility, of the fleet to which it belonged. An American admiral, speaking recently of the *Lexington* and *Saratoga*—two United States carriers which are much larger and more costly than any of ours—declared that their presence in action would be more of a hindrance than a help, since a large part of the fleet would have to be told off to defend them. All the evidence indicates that the large aircraft-carrier is falling into universal disfavor. The new ship building for the United States Navy, the *Ranger*, is of 13,800 tons, as compared with the 33,000-ton *Lexington* and *Saratoga*. Japan's new carrier, the *Ryujo*, displaces only 7600 tons, as against the 28,100-ton *Kaga* and *Akagi*. Clearly, therefore, the policy of placing all one's eggs in a few large but fragile baskets is to be reversed. A further step towards a greater diffusion of air power is the equipment of capital ships and cruisers with seaplanes, projected by catapult. In its present form, the catapult is a rather cumbersome fitting, which takes up a good deal of space on the congested deck of a man-of-war. This objection has been overcome to some extent by the ingenuity of designers, but the catapult still remains an embarrassment to all save the largest ships. Perhaps for that reason, fortified by motives of economy, it has not up to now been extensively adopted in the British Navy, only fourteen of our ships being fitted with it at present. Other Navies have gone much further, the United States, for example, having supplied all its capital ships and cruisers with from two to four seaplanes. The drawback to catapulting aircraft at sea is their inability to return directly to the vessel they have left. At the end of their flight they must alight on the water, and stay there until picked up and hoisted inboard by their own or another ship which heaves-to for the purpose. This is well enough in peace, but in war it would be highly dangerous for a battleship or a cruiser to expose herself as a sitting target to torpedo attack while stopping to retrieve her seaplanes. A rational solution to this problem is, it seems to us, the provision of special auxiliary craft which could be readily improvized out of merchantmen in an emergency. These vessels, which need neither be very large nor very fast, could be fitted with hangar accommodation, hoisting gear, and one or two catapults each. Their mission would be to accompany the fleet, retrieve its homing seaplanes, and, if necessary, send them into the air again after refuelling. Ships of this type would be kept very busy whenever active operations were afoot.

That the aircraft-carrier itself has, in one form or another, come to stay cannot well be doubted. If one fleet carried aircraft on board its battleships and cruisers only, and thus controlled but a limited number of machines, it would be liable to have its air arm overwhelmed and annihilated by the superior numbers of an enemy who possessed aircraft-carriers. We are convinced, however, that the carrier of the future should be of the smallest tonnage consistent with the performance of its functions. Since the type must in the nature of things always be exceptionally vulnerable, it is elementary prudence to build many medium ships rather than a few leviathans. Again, if the catapult can be developed to a stage at which it ceases to be an encumbrance, one or more of these projectors should be fitted to every

suitable ship in the Navy. Meanwhile, it might be desirable to improvize a "seaplane retriever" of the type outlined above, in order to gain experience with a class of ship for which war would certainly create a demand. In this connection the German invention of a "landing apron"—a flexible ramp, towed astern of a ship, on which aircraft can alight and then be hauled up on deck—seems worthy of consideration. We give the Admiralty credit for sufficient foresight to take it for granted that the whole problem of handling aircraft at sea is being carefully reviewed, and we are prepared to be told—we should, indeed, welcome the information—that all the suggestions put forward here have been duly considered, if not forestalled.—"The Engineer," Dec. 2, 1932.

CONDENSATE AND FEED PUMPS.

To those who have no more than a "nodding acquaintance" with the peculiarities of centrifugal pumps it may seem that even the most detailed discussion upon them might well be within the understanding of the veriest tyro of engineering. Little mention is made in the curricula of most technical colleges of this important method of pumping, and where the matter is included it is difficult, within the limited period devoted to the acquisition of technical knowledge, to do more than indicate to the student the lines upon which such pumps may be designed and tested. But neither educational design nor testing is likely to give the student the enthusiasm necessary if a more involved examination of such pumps is to be undertaken, for it must be confessed that at first sight there seems little that may be done to improve the performance of the centrifugal pump or to suit it to tasks which it cannot as yet efficiently undertake. Nor is that impression likely to be much altered when centrifugal pumps are encountered in practice, for it is in a sense their misfortune that they are capable of operating for long periods with little or no attention. Even when trouble is encountered, what little interest may be generated by the desire to put it right is soon damped by the discovery that practically nothing can be done to modify the performance of any given pump save only by altering the speed at which it runs. Surprise can hardly be expressed, therefore, if attention is directed rather towards other plant which, when it gives trouble, well repays the labor involved in making slight alterations by a substantial modification of performance. To their designers, however, centrifugal pumps present so great a variety of problems, partly soluble by theory, partly by experiment, that specialization becomes a necessity if a proper study of the possibilities is to be made. To more than one class of user also, the pump is so important a part of the plant that willy-nilly some understanding of its capabilities and limitations is a necessity. To none is this understanding more necessary than to the power station engineer.

It is somewhat curious that the two types of centrifugal pumps with which the mechanical engineer is most concerned, the condensate pump and the boiler feed pump, should be among those with which the greatest number of problems are connected. The coincidence is the more marked, in that the design, construction, and operation of these two types are as widely separated in the range of centrifugal pumping equipment as it is possible they can be. The condensate pump, running of necessity at a moderate speed, is designed with the one purpose of drawing water from a high vacuum, while the feed pump, running at a high speed, is usually supplied with water under a positive head and is concerned primarily with discharging it against a high

pressure. The condensate pump may have one or, at the most, two impellers; the feed pump usually several. These two types, so different in the tasks they perform, hold more of interest for the mechanical engineer perhaps than any other class, and the reason why was well revealed in the discussion of a paper presented to the North-Western Branch of the Institution of Mechanical Engineers on November 3 by Mr. T. Y. Sherwell and Mr. R. Pennington. Neither makers nor engineers-in-charge are, for instance, agreed upon the best method of operating the condensate pump, to say nothing of its design. The authors of the paper above referred to put forward with considerable strength the view that such pumps should be operated on the "throttling" curve with an unrestricted discharge, so that the positive suction head controls the output, being low for low outputs and high for high, as the pump performance dictates. But that opinion was not allowed to go unchallenged, for though one speaker agreed with the authors, with the caveat that he did not consider the method ideal, others regarded it as preferable to regulate, in some way, the standing of the condensate in the condenser. Even though criticism of the authors' views was not so pronounced, differences of opinion were also revealed by the discussion on feed pumps. It is well known that while the pressure developed by a feed pump driven by a constant-speed motor rises with reduced delivery, the resistance to the flow of the water through the pipework, valves, and heaters falls, so that at small deliveries an excess pressure which may cause trouble exists. Yet when one speaker suggested that a steam-driven was preferable to a motor-driven pump, since it could be governed to give a characteristic following closely the resistance curve, the authors pointed out that the motor was almost universally employed nowadays on account of its economy. Taking another point. Although the cause of surging in pipe lines, it is generally accepted, may be identified with the unstable characteristic to be found in certain turbine pumps, the experimental results in support of this view, which one of those present was able to lay before the meeting, were none the less acceptable. More than one speaker, however, disagreed with the authors' proposition that the best way of obtaining a stable characteristic was to incorporate one or more volute stages in a turbine pump, and believed such stages were unnecessary.

If for no other reason than that it demonstrated how largely opinions differ on the best ways of designing and operating centrifugal pumps, the discussion on the paper was of great value. Since the scope of the paper covered all classes of centrifugal pumps, it is not, perhaps, surprising that the interdependence of both condensate and feed pumps was not brought out. It would seem, for instance, that in the closed boiler feed systems that are now coming so much into favor some kind of control of the condensate pump is necessary if it is to meet the fluctuating demands of the feed pump. As to Mr. H. L. Guy's suggestion that it is "up to" the manufacturers to design a feed pump of which the characteristic approximates more closely to the resistance curve, we may remark that the conditions can be partly met by the combination steam and electric pump. Though Mr. Guy's suggestion is perhaps impossible of complete achievement it is at least an ideal towards the attainment of which efforts might well be directed. While in practice the products of the present day give good service, the paper itself and the discussion which followed undoubtedly suggest that much remains to be done if power station engineers are to be satisfied.—"The Engineer," Dec. 2, 1932.

EIGHT YEARS' SALVAGE WORK AT SCAPA FLOW.

The fifth Thomas Lowe Gray Lecture was delivered at the Institution of Mechanical Engineers, Storey's-gate, St. James' Park, on Friday, December 2, the chair being occupied by the President, Mr. William Taylor, O.B.E. The lecture was entitled "Eight Years' Salvage Work at Scapa Flow," and was delivered by Mr. E. F. Cox, of the firm of Messrs. Cox and Danks, Limited, Regent Street, London. As the rules of the Institution preclude publication of the lecture until it has been incorporated in the printed Proceedings, a short summary is all that is possible here. The salvage work described was that of raising part of the ex-German Fleet, which was scuttled in the Flow on June 21, 1919, and comprised 72 vessels, built at a cost of £40,000,000. Mr. Cox did not spend much time explaining why he undertook the work, but, after a brief outline, proceeded to a description of the actual operations. With disarming candor he explained that he had had no previous experience in salvage work, and from time to time referred to the difficulties into which that want of experience had led him, and how, as he gained knowledge, they became less formidable. As the lecture proceeded, it became clear, however, that he has now gained a complete mastery of marine salvage technique, and that by handling such a number of ships over such a long period, by employing a number of men continuously, and by investing large amounts of capital in plant and material, he may be said to have raised salvage from an isolated operation to an industry.

The first part of the lecture, which was copiously illustrated by lantern slides, was devoted to an account of raising some of the sunken destroyers, of which 25 were salved between August 1, 1924, and April 30, 1926. Of these destroyers, all but one, which was partly ashore, were lying on the bottom, 12 of them on their sides, others bottom upwards, and the remainder upright. Eighteen of them weighed 750 tons each, and seven 1300 tons each. The destroyers were raised by wire-rope slings passed underneath them, the chains, used initially, proving unreliable. The ropes were passed over pullies arranged on a long shaft extending along the inner edges of two pontoons formed by cutting a floating dock in half. The early part of this work was described in "Engineering," Vol. cxviii, pages 233 and 373 (1924).

Mr. Cox described, by means of blackboard sketches, the method of slinging the differently-placed destroyers. In the case of those lying upright, the wire ropes were passed under the stern through the opening above the propeller shafts forward of the propeller brackets. The vessel was then tilted up with its fore part as a fulcrum, and further ropes were passed under the keel until the whole hull was supported. The ropes, 12 in number generally, were distributed as evenly as possible, the floating dock being moved along as required. With a vessel lying on its side, a somewhat similar procedure was followed, though the operation was more difficult. The vessel was first lifted clear of the bottom. The ropes were arranged in this case to form endless slings, so that by synchronous turning of the pullies, the vessel was turned over into an upright position, and was then hoisted to the surface. In some cases this turning operation only occupied one morning. When the destroyers had sunk upside down, the work was easier and the vessel would rest on her bridge and forward gun, so that there was a 6-foot space or thereabouts through which the slings could be passed by the divers. The vessel was then lifted clear and the docks, with the suspended destroyer, were towed into deeper water, where the latter was turned over by the slings into an upright position. Two days were taken by this operation. There were also some exceptional cases. When the fleet had been handed over, three destroyers had been tied to one buoy, and, on sinking, had piled one

upon the other. This involved special arrangements, but all three vessels were successfully raised. The general methods employed in raising the destroyers became so effective that the last one was brought to the surface in only four days. The initial cost was considerable; £40,000 had been spent before the first destroyer was lifted, there were, for instance, 100 special pulley blocks, each costing £100, and 24 hand-operating winches. Some additional particulars of this part of the work were given in "Engineering," Vol. cxix, pages 476, 743 and 801 (1925).

Passing on to the larger vessels, Mr. Cox then described, again with the aid of the blackboard, the work done in salving the 28,000-ton battle-cruiser *Hindenburg*. The vessel was settled in an upright position on the bottom, with her masts, funnels and other upper works exposed, and was lifted by closing all the openings and pumping out the interior until she floated. The great difficulty, however, was that of keeping the vessel upright as soon as she began to get buoyant, and at one time she was allowed to settle down again and work was stopped for more lucrative operations. Up till this point £40,000 had been spent; indeed, before final recovery, she cost Mr. Cox £75,000, which he just got back by her sale as scrap. Over 800 cover plates had to be put on the ship to make her water-tight, one alone, attached under water, costing £500. The men did the work very effectively, and when the first pump was started, the water immediately began to go down, which showed that there were no important leaks.

The real difficulty was that of rendering the water in the several compartments immobile, owing to the fact that there was intercommunication between them by means of large pipes in the double bottoms. The various valves on these pipes had all been opened at the time of scuttling, and the operating spindles disconnected, so that they could not be controlled. As the ship was resting on solid rock at the stern, which was lower than the stem, and as the dewatering pumps had been fitted forward, the water could not be got at at the stern, the more so when increasing buoyancy lifted the forepart. In this condition the ship was balanced on the after part of the keel, which was about 3 feet wide, and as the total width was about 104 feet, it was impossible to level her, a heel, which eventually reached 35 degrees, taking place. Mr. Cox then described in great detail the methods he had employed for preventing this heeling until the vessel was sufficiently far out of the water. These included propping up the ship with sections of destroyers filled with concrete, and the use of submersible pumps. He concluded by describing the dramatic moment when the ship finally began to lift, with 15,000 tons of loose water aft, and as she rose commenced to heel over. This went on as the pumps continued to work, and finally the indicator reached 6½ degrees, to stop there, however, and later to return to 6 degrees, which was never again exceeded. The vessel was then successfully floated.

The next two operations described were those of salving the battle-cruisers *Moltke* and *Seydlitz*. The *Moltke*, of 23,000 tons, was lying bottom upwards; the *Seydlitz*, of 25,000 tons, lying on her side. Mr. Cox described how he had conferred with Italian salvage experts who had been concerned with a somewhat similar case to the *Moltke*, and had decided to displace the contained water by compressed air. After many difficulties had been met with and overcome, the vessel was raised on June 10, 1927, and was later towed upside down to Rosyth, and berthed in a dry dock there in that position without incurring more damage to the dock than was covered by the sum of £8. As a full illustrated account of the raising and berthing of the *Moltke* was given in "Engineering," Vol. cxxiii, page 741 (1927), and Vol. cxxv, page 737 (1928), these articles may be referred to for further information.

The *Seydlitz*, some account of the earlier operations on which will also be found in the first of the two articles above referred to, was described by Mr. Cox as being the most troublesome of all the ships dealt with. The armor plating of the side lying above the water had been removed to facilitate some of the preliminary operations, and the ship was, after a great deal of trouble, turned over so as to float keel upwards. After having got her level, she was towed down to Rosyth upside down. As one side had been largely stripped, the ship required careful handling on the voyage down, and he thought the men who volunteered for the journey were very plucky. The eight years' work had been carried out with very few accidents; only three lives had been lost—due, it was regrettable to say, to the carelessness of the persons concerned. The next ship referred to was the 24,500-ton battleship *Kaiser*. This was lying bottom upwards with a list of 8½ degrees, but was recovered in a vertical position, which simplified subsequent operations considerably. This question of list, Mr. Cox said, was very important; if a ship could be brought up level the remaining handling was quite straightforward.

At this point Mr. Cox was obliged to break off owing to the lateness of the hour, but he kindly volunteered to give an account of his work on some vessels not touched upon on another occasion. In order to give some measure of completeness to this account, it may be mentioned that these vessels included the 4000-ton cruiser *Bremse*, lying on her side; the 20,000-ton cruiser *Von der Tann*, lying bottom upwards, and the 25,000-ton battleship *Prinz Regent Luitpold*, lying bottom upwards with a list of 20 degrees. In all, Messrs. Cox and Danks have raised since August, 1924, vessels aggregating to 172,100 tons.

The president, in proposing a vote of thanks to Mr. Cox, said that the account they had listened to was one of the most thrilling stories of courage, enterprise, and determination that had ever been heard in that hall, and the man who had carried the work through was, he was proud to say, an Englishman. He would like to take the opportunity of thanking Mr. Cox for his offer to deliver a second lecture, and he felt that every effort should be made to take advantage of it.—"Engineering," Dec. 9, 1932.

STRESSES IN BOILER TUBES.

Attention has been called in recent years to the high stresses set up in the tubes of steam boilers due to high rates of heat transfer from burning fuel and products of combustion to water boiling within the tubes. To get a more accurate picture of the stresses in thick boiler tubes subjected to high rates of heat transfer, an investigation made of the subject was reported in a paper by William L. De Baufre.

The stresses were investigated for non-uniform heat absorption around the tube circumference, as well as for uniform rate of heat absorption. The difference in temperature between the inside and outside surfaces of the tube was shown to vary from about 10 degrees at low heat rates and low steam pressures to as high as 123.5 degrees at high heat absorption rates and high pressures.

The investigation has shown that where the stresses produced by heat transfer and internal fluid pressure exceed the elastic limit of the material near the inner and outer surfaces of the tube wall, the calculated stresses based on perfect elasticity are greatly reduced by plastic flow, but residual stresses are thereby set up when heat transfer ceases and the internal fluid pressure is reduced to zero. Every time a boiler goes into and out of operation, a stress cycle from tension to compression occurs of considerable

stress range. This stress range is greatest for the circumferential stress at the inner surface of the tube wall when the tube is heated uniformly. When heated non-uniformly, the actual stress range may exceed the circumferential stress range under certain abnormal conditions. It is shown by comparison with experimental data, however, that a boiler tube will not fail within any reasonable period of time by fatigue from these repeated stress reversals.

Before a boiler tube can fail by bursting, all portions of the tube wall may be stressed to a point where more or less rapid creep will occur. The investigation shows that before this can take place all heat transfer stresses will be entirely neutralized by creep. Failure of the tube then occurs by the stresses due to internal pressure only. A measure of the safety of the tube is the ratio of the stress which will cause creep under the mean operating temperature of the tube wall to the mean stress caused by internal fluid pressure.

Increase in tube safety is secured by using thicker rather than thinner tubes than called for by the A.S.M.E. Boiler Code. An increase in safety may also be obtained by using material which will not creep until a higher stress is reached, such as a medium-carbon steel in place of mild-carbon steel. Even with mild-carbon steel subjected to a very high rate of heat absorption, failure can occur only when the coefficient of heat transfer from the inner surface of the tube wall to the water-steam mixture within the tube is reduced to an abnormally low value. Boiler-tube failures therefore occur by reason of poor circulation of the water-steam mixture within the tube, by accumulation of scale on the inner surface of the tube wall, by corrosion, or by defective material, rather than by any stresses due to unequal expansion within the tube wall caused by high rate of heat absorption.

In discussing Professor De Baufre's paper, Mr. Orrok expressed the belief that the margin of safe tube temperature would be less with a thick tube than with a thinner tube. He agreed that a thicker tube would be immune to fatigue failure, due to one shutdown and starting up of a boiler per day, but pointed out that there were parts of a boiler where similar stress cycles were occuring all the time, and that these points would be subject to fatigue. He stated that the outside wall temperature was of great importance, and should be kept with reasonable limits. In connection with the use of high-carbon and alloy steels for boiler tubes, he pointed out that the tube thickness would be affected by the change in the heat conductivity of the higher strength materials, the conductivity decreasing in the order of 48 to 16 for the high-carbon and alloy steels.

Dr. Jacobus pointed out that tube failures almost invariably were due to deposits on the inside of the tube. He also presented figures comparing the tube thickness allowed by the new German boiler code. This code permits lesser wall thicknesses than does the A.S.M.E. Code, but at the same time permits steels of higher tensile strength. He also suggested that boiler designers would be greatly interested in the author extending his figures to heat transmission rates of 125,000 to 150,000 Btu. per hour.

C. F. Hirshfeld suggested that much may be learned about the creep of metals at high temperatures by studying the action of lead under normal temperatures. He disclosed that tests on lead at very low temperatures had indicated that this material would produce a stress strain curve similar to steels at normal temperature. In closing the paper, Professor De Baufre pointed out that the creep occurs on the inside of the tube. He also said that he had made up curves which attempted to correlate heat conductivity with the varying composition of steel, and it was his opinion that heat conductivity did not vary with high- and low-carbon steel as much as Mr. Orrok had indicated.—"Power," Mid-December, 1932.

THE ENGINEER IN PUBLIC LIFE.

By Dexter S. Kimball.*

An unusual feature of this period of industrial depression is the ever increasing outpouring of talks, magazine articles, pamphlets, and books by engineers discussing the economic problems that confront us. During the last year, as a member of a committee of the American Engineering Council it has devolved upon me to read a large amount of this literature, which varies from suggestions that obviously are of no help, to some profound studies of our present economic system and its defects. Of course, for many years a few forward-looking engineers have given thought to economic subjects, but the present activity is so great as compared with that of former days that one is led naturally to inquire into the reasons for this outburst. An examination of the growth of the engineer and engineering literature would appear to indicate that the phenomenon is quite logical and to be expected. Whether the engineer is to be of marked service in such matters remains to be seen.

To many persons the idea of the engineer as a figure in public life is a new one, to say nothing of his appearance as an economist. But the increasing importance of engineering projects and of the manufacturing methods that the engineer has promoted were sure to push him into the limelight of public affairs. Not a few engineers have occupied such high offices as governors of states, and many have served on important governmental commissions, but without doubt the election of President Hoover has been the greatest encouragement to engineers to take a more prominent part in civic affairs. Is the engineer to be a prominent figure in the field where the lawyer and politician have been supreme?

During the last half of the last century the engineer was busy building up the vast and complicated industrial machinery which is now troubling us so much. He was rarely heard of in any other capacity. By the end of the century he had solved the problem of production for the first time in the history of mankind, and almost the first printed doubts of the economic consequences of his methods are found in the Census Reports of 1900. It was inevitable that this experience should be accompanied by great growth within the minds of engineers themselves, and engineering emerged in the new century as a scientific profession, whereas in 1850 it was largely a handicraft calling. Two major influences hastened these changes. The first is the essential nature of engineering, which leads naturally to an orderly method of thinking, not only as regards engineering, but also as regards all manner of problems. The second and greater influence has been the engineering colleges, of which the Land Grant engineering colleges constitute the large majority. The growth of engineering education during the last seventy-five years has been remarkable, and, in the last analysis, the college professor has been mostly responsible for the industrial development we now behold.

The progress of engineering thought and practice during the last fifty years or thereabout can be traced admirably in the proceedings of the several national engineering societies. A good illustration is The American Society of Mechanical Engineers, founded in 1880. The early volumes of this society are decidedly "shoppy," and there is much discussion of elementary matters that have long since ceased to interest engineers in any large degree. Before long, however, scientific papers of real merit begin to appear, especially those

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concerning the theory of the steam engine and the strength of materials. As early as 1886 Henry R. Towne had presented a paper entitled "The Engineer as an Economist," and in 1889 he presented one of the first modern gain-sharing plans in another contribution to the society's Transactions. But progress was slow, and engineers as a whole were concerned with technical matters. In 1903 Fred W. Taylor presented his epoch-making paper on "Shop Management," and this marks a new era in engineering literature.

It is almost unbelievable, looking back upon the progress of 30 years, to realize that this great paper, destined to change all of our ideas of manufacturing economics, was not only poorly understood, but even less appreciated. It is hard to believe that even ten years after Taylor's paper was presented it was sometimes difficult to get a hearing before this society for papers on the economics of production, but that this is a fact I can vouch for from personal knowledge. This is all the more remarkable when it is considered that 75 per cent of all engineers who graduate from college eventually find their way into administrative work of some kind.

But if progress was slow it was sure, and engineering has emerged not only as a recognized profession, but also as one that has an intimate knowledge of industry possessed by no other group. And a part of this intimate knowledge is economic. A number of influences have forced this knowledge upon the profession. In industry the increasing pressure of competition has compelled the industrial engineer to develop a manufacturing economy almost wholly new. The electrical engineer was one of the first to be confronted with the need of a new manufacturing technique, which brought him into close proximity with manufacturing economy. In the case of the civil engineer the very magnitude of his projects has brought him face to face with economic problems of large size. Thus consider the new proposed bridge over the Golden Gate at San Francisco, which will have, if it is built, the longest span ever erected. So far as I am informed, no one has questioned the ability of the engineer to erect this giant structure, but the economics of the undertaking are much debated. This is typical of much of the work of the engineer today. The question, "Can it be done?" is not asked, but rather, "Should it be done from an economic standpoint?" From the very nature of his position in society, the engineer, if he is to rise to his opportunity, must be more of an economist than he is at present.

It is quite commonly assumed by some that the experience of the engineer in industrial economics should fit him to speak authoritatively upon the broader problems of political economy. It is quite true that the engineering administrator is brought into close contact with such matters as tariffs, taxes, transportation problems, foreign trade, etc., etc., and it is often assumed that to these problems he can bring the same methods of solution that he has found to be so successful in industrial problems. In many instances this is true, as illustrated by the excellent work already accomplished by the American Engineering Council in a field which a few years ago was unknown territory to engineers. Unquestionably where facts or tangible evidence can be obtained, engineering methods are very effective in arriving at accurate conclusions, and the engineer is in a peculiarly advantageous position in obtaining such tangible evidence, as can be gathered from the industrial field. However, in the case of our most difficult problems of general economics, exact facts and tangible evidence are not easy to obtain, and oftentimes the evidence is voluminous and conflicting. In many such cases the well-trained business man, or the lawyer, is just as capable, or more so, of drawing an accurate conclusion as any one else. Certainly the engineer has no advantage here unless the data are drawn largely from industrial sources with which he is more familiar than are others.

As Prof. Seymour Garrett, himself a well-trained engineer and also a successful teacher of economics, has well said:

"I said above that the impossibility of drawing valid conclusions directly from the observation of events applied as well to current as to past economic affairs. I am aware that there is at the present time, and has been for some time past, a disposition to assume generalized theory unimportant. It is assumed that detailed statistical inquiry will reveal truth aided only by common-sense and general information. With this view, engineers, because of the nature of their own work and of their triumphs, have a natural sympathy. They instinctively applaud what they denote as an appeal to facts instead of theory. What they forget, and sometimes do not even sense, is that the problems of engineering and of economics present large differences of kind. This is partly because the phenomena with which engineering deals occur in simpler form than those of economics. It is commonly possible to see without conscious effort just what is the nature of the data needed for a proper solution. Also the basic generalized theory within which the engineer works has been developed so long since that he uses it automatically and almost unconsciously."

If, then, the engineer is to be an important figure in public affairs he must acquire a broader technique than that which he ordinarily possesses, and he must inform himself concerning a wide range of subjects of which ordinarily he knows little. Furthermore he must acquire a wide knowledge of economic history and be able to trace the effect of economic changes over long periods of time. The broad economic problems that now trouble us are not isolated and circumscribed in character; most of them have long histories and many ramifications. It is true that some of the old economic theories developed in a handicraft age do not apply to our modern machine era, and the industrial engineer can do much to show their fallacious character. But on the whole the engineer who aspires to solve modern economic problems must expect to do an unusual amount of studying before he can replace these old theories with others that are suited to our day and methods. Perhaps no field of knowledge presents such a bewildering array of theories which purport to tie together groups of phenomena more or less vaguely connected. He is indeed a bold man who will speak dogmatically about problems in political economy who has not studied this so-called "dismal science" long and carefully as a preparation. If the engineer can apply his analytical methods to these vague relations and develop the basic facts through his more intimate knowledge of industry, he can indeed become a most useful factor in public life.

And in this preparation the assistance that the university may offer is comparatively small. It can provide the embyro engineer with a fair knowledge of industrial economics concerning plant location, plant design, plant operation, and plant administration. But in the broader field of general economics the best the university can do is to give him some fundamental training and some instructions as to the general character of these broader problems. The time available in the four- or even five-year course does not permit of anything more. But obviously if the college is to perform its duty to the engineer, who is sure to be brought into contact with world problems, it should do what it can along these lines. Not all or even many will become important figures in public affairs. That statement holds true for all college men from whatever course of study. But it would appear that the engineer who will take the time and trouble to inform himself concerning our broader economic problems should, with his peculiar knowledge of the industrial field, be able to make some very constructive suggestions that would be helpful in times like these.

There is another and most important reason why broader economic knowledge is essential for the engineer, and that is the group consciousness now appearing among the profession. Only brief reference can be made here to this phenomenon. It has been said that one of the outstanding indices of a profession is the development of a "jargon" of its own that others cannot understand. In this the engineer, like the doctor and lawyer, has been highly successful. The second great index is a tendency on the part of engineers to exclude all but the elect from their group, as is the case with the medical, legal, ministerial, and other professions.

Until lately there has been little tendency among engineers to become an exclusive group, but the rapid growth of licensing and correlated movements indicate that a new era in this respect is under way. I have no quarrel with licensing if it be justifiable. If the engineer has become or will soon become such an important figure in the public eye that he should be licensed in order to protect the public, as is the case with the doctor, or lawyer, there can be no logical objection to such a procedure. If this is to be the case, the engineer must bestir himself and make himself fully worthy of such distinction. The lawyer not only practices law, but he is also a public servant in the creation and adjustment of law through his bar associations. The doctor not only attempts to relieve suffering directly, but he is a most important servant in matters of public health. If the engineer is to be granted exclusive privileges in his own narrow professional field, he must make himself not only master of this narrow field, but also of its ramifications as it affects public welfare. In the past he has proceeded blindly to develop a technique of production, which, while supplying the necessities of life in abundance, has created economic and social problems that stagger the mind of our best economists. It is high time that he himself tried to understand what he is doing, and if possible offered remedies for the economic troubles he has caused; and this will undoubtedly take him far afield in his studies along the lines indicated in the foregoing. Licensing, I believe, can be defended only upon such grounds. As a gild or a trade-union measure it is indefensible. It will be interesting indeed to see what the engineer will do with such a great opportunity.—"Mechanical Engineering," Jan., 1933.

THE DICTATORSHIP OF SCIENCE.

Within recent years many thoughtful students and observers of our political organization have, in one form of words or another, expressed the opinion that the time has come for a wide infusion of the scientific spirit into that organization, and for the adoption, on a generous and wholehearted scale, of scientific methods for resolving all questions affecting the nation's well-being and good government. Too long, they argue, have we been at the mercy of party prejudice and political dogma. Strong lungs, long purses, and the interplay of personality have been the chief factors determining our destiny. The growth in the influence of science on our everyday lives demands, it is urged, that these time-worn forces should no longer be allowed to shape the affairs of State, that they should be abolished, and that they should be replaced by the calm, unbiased scrutiny of a senate imbued with the scientific spirit. The views commonly expressed on this subject are as yet largely uncrystallized. Few of the advocates of reform go so far as to recommend that our national legislative body should be, out and out, a parliament of scientists; that is to say, of men who before being called to the service of the nation had devoted their lives to the study of science in one or other of its many branches and had obtained eminence therein. For the most

part, the reformers would be content if our legislators and rulers would openly and loyally agree to accept Science as their leader and would cultivate and adopt the scientific habit of mind in their treatment and discussion of all questions laid before them for their decision. Even on this limited basis it is not wholly self-evident that the reform is practicable and desirable. But, granted that it be both, it is very certain that the changes wrought by its introduction would be momentous and revolutionary to a degree to which the nation as a whole would probably hesitate to proceed.

The scientific outlook cannot be acquired in a day, like a pair of new spectacles. Only in rare cases can it be acquired at all, even with the most diligent study, by anyone who has reached middle life without it. It represents a certain orderliness of thought and argument, and openness of mind before coming to a conclusion, which have their roots in early training, and which, if not sown in our youth, will not attain vigor in later life. To educate our present race of parliamentarians to take a scientific attitude towards their duties would be a hopeless task. The attainment of the reformers' desires would necessitate the recruitment of Parliament from a body of people trained to the scientific outlook from their schooldays, trained, that is to say, to science as a cultural study rather than as an aid to technical ends. Herein it becomes clear that the reform is dependent upon a great antecedent reform—in many ways doubtlessly a very desirable reform—in the attitude of Education towards science. The change in our political organization would be of a further momentous and revolutionary character in that, sooner or later, it would inevitably end the parliamentary party system as we now know it. Just as science is international, so does it recognize no party. Newton's laws of motion are as binding upon the Labor Member as upon the Conservative, and so, too, will be the laws of economics and sociology, once they have been as firmly and as certainly established. The reform would leave no necessity and no opportunity for an Opposition. Guided by the undisputable dictates of science, all decisions, in the ultimate ideal stage of the reform, would be reached unanimously, unless some Einstein of the back benches arose to challenge and upset accepted scientific doctrine. Again, science at the hustings would be a sorry sight. We could not, with dignity, allow candidates to set their scientific qualifications in competition, nor would it be reasonable or safe to leave the electors to exercise their judgment in the capacity of examiners in science which would be thrust upon them. Some fresh method of selecting our legislators would be required, some method in which the votes of the populace would play no part, some method perhaps based on appointment by dictatorial authority. These and other great changes in our political organization which the reform would involve might not be immediately and spontaneously accepted by the nation as a whole, although it is conceivable that a minority might regard them with equanimity, and possibly even as blessings. They certainly do not constitute by themselves any insuperable objection to the suggested reform or any reason for condemning it out of hand. A different aspect, however, is revealed when we come to consider the practicability and desirability of the reform. Behind the suggestion there lies a belief in the scientist as a species of superman, or, at any rate, an exaggerated faith in his ability to think and decide correctly on all questions, whatever their nature, that might be laid before him. Long contact with scientific circles has taught us that outside his own department the scientist is, in general, a trifle impractical, a little unworldly, distinguished by his modesty and by his readiness to confess ignorance on subjects which being beyond his domain he has never studied and does not understand. His instinct is to shun hasty judgment and

to express no opinion on any subject until, by experimental or other means of investigation, he has gathered together, sorted out and analyzed all its details. Science does not deal with opinions, but with established facts. The very essence of politics is its opinions, and we are fully persuaded that in its atmosphere the scientist would either become dumb or would cease to be scientific.

At the present moment science has little real cause to complain of being neglected in the conduct of the nation's business. There never has been a time when scientists were consulted more frequently than today by politicians when framing their programs and legislation, and, it may be added, when their advice and guidance were more readily accepted and made effective. No Act is passed, no policy is set up, if it embodies technical considerations, without the help of a committee or commission composed of scientists or before which scientists are given every opportunity to make their voices heard. To elevate the scientist from the committee-room to Parliament itself, to place in his hands power to enforce what he is now permitted to recommend, would be to the advantage neither of the nation nor the scientist, and might be dangerous. It is entirely against our constitutional practice to have a professional sailor as the First Lord of the Admiralty or to have other than a civilian Secretary of State for War. There are sound reasons for that practice, and, let our lives become still more and more prescribed and circumscribed by the advancement of science, there will always be equally sound reasons against placing scientists in legislative control over the nation. We cannot shut our eyes to the fact that the non-scientific public distrusts and fears scientific progress. It counts the benefits which it has received from it, but it sees, or believes it sees, in it the cause of many modern evils in our social organization. Science itself has still not the shadow of an opinion to offer as to whether its ultimate development will be for the good or the hurt of mankind, whether it will heal our woes or destroy us. Until that point has been resolved beyond all doubt it will be wise, both scientifically and politically, to keep science as a servant, and to avoid any voluntary action encouraging its dictatorship.—"The Engineer," Jan. 13, 1933.

THE HOWDEN-JOHNSON HEAT-RECOVERY SYSTEM.

The Advent of the Funnelless Steamship.

The remarkable reaction in favor of steam propulsion, which has become increasingly evident during the last few years, will undoubtedly gain in force by the revolutionary developments in stokehold practice and the system of waste-heat recovery now being introduced by Messrs. James Howden & Company, Limited, in collaboration with Mr. John Johnson. The last-named, as is well known, has been prominently identified with the construction and operation of a variety of modern steam installations.

The history of the firm of Howden during the last 75 years has been closely identified with the economies effected in steam plants, particularly so far as the boilers are concerned. Pioneers in waste-heat recovery at sea, they have been largely responsible for the progress of air preheating both in marine and land installations. The Howden-Ljungstrom air preheater, it is claimed; offers the maximum recovery possible in this direction; but with air preheating alone the maximum boiler efficiency which it is possible to attain, keeping the air preheater within commercial limits, is seldom much above 88 per cent. The desire to recover a substantial proportion of the remaining

12 per cent of heat still being lost has led Messrs. Howden to adapt their experience of modern power-station practice to the problem, while at the same time satisfying the onerous requirements of marine conditions.

The object which has been kept in view is the utilization not only of the sensible heat, but also the latent heat, of the moisture in the waste gases. This is accomplished by means of the system outlined in Figure 1, from

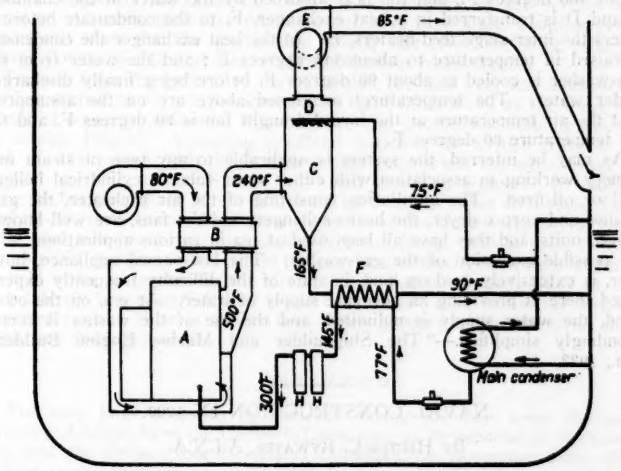

FIG. 1.—DIAGRAMMATIC ARRANGEMENT OF THE HOWDEN-JOHNSON SYSTEM.

which it will be readily seen that arrangements are provided for washing the gases and extracting the heat by means of the washing water. It is consequently unnecessary to retain the ship's funnel in order to dispose of the clean, cooled gases, which can be discharged through the side of the ship, leaving the structural arrangements of the upper part of the vessel to be designed without regard to the restrictions hitherto imposed by the uptake casings.

This almost complete utilization of the waste heat, we are informed, brings the boiler efficiency into the region of 95 per cent, and in service a maintained efficiency considerably in excess of 90 per cent may be confidently expected. The effect on the fuel consumption of such figures is obvious, but further—perhaps less obvious—consequences are reduced weight and bulk of bunkers and machinery, with correspondingly increased cargo capacity.

The apparatus involved in this system is all of the simplest type, and the total cost of the complete ship incorporating the Howden-Johnson system will probably be less than that of the present conventional vessel. The diagram given in Figure 1 shows the main features of the system and illustrates the simplicity of the means employed.

The gases leave the boiler, A, at a temperature of 500–550 degrees F. and pass through an air preheater, B, which reduces the temperature to 240 degrees F. Thence they pass into a gas-washing chamber, C, where they meet a supply of water from the main-condenser discharge, which cleans them and

reduces their temperature to about 85 degrees F. The gases then enter the vortex chamber, D, where any water which they are carrying is separated, and the dry, cooled gases are finally discharged by the induced-draught fan, E, through a duct leading overboard.

The heat recovered from the gases in the preheater is taken up in the usual way by the air for combustion, which is raised in temperature to about 400 degrees F., and the heat absorbed by the water in the chambers C and D is transferred in a heat exchanger, F, to the condensate before it enters the inter-stage feed-heaters, H. In the heat exchanger the condensate is raised in temperature to about 145 degrees F.; and the water from the gas-washer is cooled to about 90 degrees F. before being finally discharged under water. The temperatures mentioned above are on the assumption that the air temperature at the forced-draught fan is 80 degrees F. and the sea temperature 60 degrees F.

As may be inferred, the system is applicable to any type of steam machinery working in association with either water-tube or cylindrical boilers, coal or oil-fired. The auxiliaries, consisting of the air preheater, the gas-washer and vortex dryer, the heat exchanger, and the fans, are well-known, proved units, and they have all been used at sea in various applications, with the possible exception of the gas-washer. The last-named appliance, however, is extensively used on land, in spite of the difficulty frequently experienced there in providing an adequate supply of water. At sea, on the other hand, the water supply is unlimited, and the use of the washer is correspondingly simplified.—"The Shipbuilder and Marine Engine Builder," Jan., 1933.

NAVAL CONSTRUCTION IN 1932.

By Hector C. Bywater, A.I.N.A.

INTRODUCTORY.

The outstanding event of the year in the sphere of Naval shipbuilding was the decision of France to lay the keel of a battle cruiser, the *Dunkerque*. Work on this ship is reported to have started at Brest during the last week in December. If this news is authentic, it signifies the termination of the capital ship "holiday" which was inaugurated by the Washington Treaty and has lasted almost exactly ten years, reckoning from the date (December 28, 1922) when the keel-plates of the *Nelson* and *Rodney* were laid simultaneously at Elswick and Birkenhead. However much opinions may differ as to the practical value of the disarmament negotiations which have been intermittently in progress since 1921, it cannot be denied that the complete and universal stoppage of battleship construction over a full decade was a diplomatic achievement on no mean order. Nor does the building of a single capital ship by one Power necessarily herald a general rupture of the truce. While the action taken by France may have local repercussions, foreshadowed by the reported intention of Italy to build a "reply" to the *Dunkerque*, there can be no question of any resumption of heavy construction by Great Britain, the United States, or Japan before 1936, when the London Treaty expires.

To appreciate the material results of the "holiday" it is necessary to recall the building commitments of the leading Naval Powers when the Washington Conference assembled. Great Britain had placed contracts for four battle cruisers of 47,000 tons, and prepared designs for a quartet of still larger battleships, to be laid down in 1922. The United States was at work on sixteen capital ships, ranging from 32,500 to 43,000 tons, and Japan had an

equal number of ships of approximately the same dimensions on the stocks or *in petto*. These forty leviathans represented a first cost of at least £320,000,000, and their maintenance in full commission would have averaged £500,000 a year per ship, yielding a total of £200,000,000 for the ten years ending in 1936. But, as a result of the Washington Treaty, thirty-five of the projected ships were scrapped or cancelled, leaving only five intact—a total subsequently increased to seven by the building of the *Nelson* and *Rodney*. After the necessary readjustments have been made, a simple calculation will show that the capital ship holiday has saved the three principal Naval Powers a collective sum of £430,000,000 in round figures.

Turning from the general to the particular, the past year has witnessed a further decline in the relative strength of the British Navy as the three-fold result of economy, unilateral disarmament, and exceptional building activity by foreign Powers. According to official statistics, the British Navy at the end of 1932 stood fifth in destroyer and submarine tonnage—reckoning "under-age," *i.e.*, effective ships, only—and second in cruisers. In contains a far higher percentage of obsolete material than any other first-class Navy, and its *personnel* is now 20,000 less than that of the United States Navy, and only 4000 tons more than that of the Japanese Navy. While these facts do not, strictly speaking, come within the province of this review, their inclusion is held to be warranted by the circumstance that the British Navy in 1933 is relatively less powerful than it has been at any time within the last two hundred years. That is a new fact which appears to justify some slight departure from precedent.

BRITISH EMPIRE.

The only large ships to be launched during the year were the sister cruisers *Achilles*, from the Cammell-Laird yard at Birkenhead on September 1st, and the *Orion*, from Devonport Dockyard, on November 24th. Both belong to the 1930 program. The third cruiser, *Neptune*, is to go afloat at Portsmouth early this year. All are units of the *Leander* class—see Supplement—which was fully described in last year's review. They are 554½ feet in length, with a beam of 55 feet 2 inches, and a draught of 16 feet at the standard displacement of 7000 tons. The designed horsepower is 72,000, equivalent to 32½ knots. This power is only 8000 units less than that developed by the machinery of the 10,000-ton cruiser *Dorsetshire*, which has a speed of 32¼ knots, the disproportion being accounted for by the reduced length of the 7000-ton ships—554½ feet as against the *Dorsetshire's* 630 feet. The *Achilles* and her consorts stow 1800 tons of fuel oil, or little more than half the quantity carried by the *Dorsetshire*, but their cruising endurance of 7000 miles appears to be adequate. It has been found possible to work vertical armor in way of the machinery spaces, and as the hull is closely subdivided the ships are reasonably well protected. The armament consists of eight 6-inch guns paired in turrets, with four 4-inch A.A. guns and six torpedo tubes. In general, therefore, the design must be considered satisfactory, but the estimated cost of £1,600,000 is far too high for this class of vessel. It is all-important that building cost should be reduced in view of the enlarged cruiser programs which must be undertaken when the present Treaty restrictions are modified. Even a slight sacrifice of speed would effect a considerable saving, and probably there is scope for retrenchment in the armament and other equipment, which, in all recent ships, has been designed on a very elaborate scale.

Two other cruisers of the 7000-ton type, *Ajax* and *Amphion*, will shortly be in hand, and two more are to be ordered next March. A new class is

represented by the *Arethusa,* now under construction at Chatham. From unofficial reports, she has a displacement of 5450 tons, the speed being 32½ knots, and the main armament six 6-inch guns. A second ship of this class was sanctioned in the 1932 Estimates. Owing to the cancellation of the 1928 program, and the delay in building the solitary cruiser (*Leander*) authorized in 1929, no new cruiser was completed in 1932. As the 1931 program has also been retarded for reasons of economy, the *Ajax, Amphion* and *Arethusa* will not be ready before the spring of 1935, though, in the normal course, they would have been completed in the previous year. Meanwhile, large groups of war-built cruisers are becoming obsolete every year, but are not being replaced. At the present time only forty-three British cruisers are within the age-limit of sixteen years, and by the end of 1934 the total of under-age ships will have shrunk to thirty-four. If, therefore, our cruiser establishment is to be maintained at the total of fifty which the Admiralty has fixed as the irreducible minimum, it will be necessary to retain in service sixteen ships which have passed the limit of effective life.

Eight destroyers of the "D" class, built under the 1930 program, went afloat during the year and are now passing into service. Except for a slight increase in tonnage, they are replicas of the "A," "B," and "C" boats, displacing 1375 tons, with machinery of 34,000 S.H.P. The contract speed has been raised from 35 to 35½ knots and was in every case exceeded on trial, the *Daring,* for example, reaching 38.2 knots on her full-power run. The flotilla leader *Kempenfelt* was commissioned during the year, and a sister vessel, *Duncan,* is in hand at Portsmouth. In spite of their official rating they are neither larger nor faster than the latest destroyers, from which they differ only in having extra staff accommodation. Including those of the 1932 program, which will not be ordered until the end of the financial year, fifty-two destroyers have been authorized since the war, but the last boats will not be ready before the autumn of 1934. They are smaller and less powerful in every way than contemporary foreign craft, the average cost being slightly under £300,000. Naval opinion as a whole approves the policy of keeping to moderate dimensions instead of emulating foreign practice by building "destroyers" which in size and armament are light cruisers. Numbers are our chief requirement in this type, and it would be a palpable blunder to sacrifice numerical strength to greater individual power.

The large submarine *Thames* is now in commission. Her displacement of 1760 tons exceeds that of any British post-war submarine excepting the *X1,* and is not likely to be surpassed in the near future, a reduction having been effected in the tonnage of the heavy type boats *Porpoise* and *Severn,* authorized in 1930 and 1931 respectively. Other submarines completed during the year were the *Swordfish* and *Sturgeon,* the first of a new coastal type introduced under the 1929 Estimates. Their displacement is only 640 tons, but they have proved remarkably seaworthy, and their armament of six torpedo tubes in the bow, besides a 3-inch gun, is formidable. Four more of this class are building or on order. The tendency to reduce dimensions is very noticeable in all vessels now under construction for the British Navy, and is doubtless inspired by motives of economy. At the same time it deserves to be emphasized as an instance of qualitative reduction in Naval power, and therefore as a practical contribution to disarmament. Unfortunately, no other Power seems inclined to follow our lead in this direction.

The net-layer and target-towing ship *Guardian,* of 3050 tons, was launched at Chatham in 1932. Her design appears to be experimental, and further details are awaited with interest. The estimated cost is £406,900. A destroyer depot ship, included in the 1932 program, is to be ordered towards the end of the financial year.

UNITED STATES.

The largest ships launched in the year under review were the 10,000-ton cruisers *Portland* and *Indianapolis*. They differ from their eight predecessors by having a slightly reduced speed and vertical armor protection, but in view of the very limited margin of weight available their defensive qualities must still be limited. Five further ships of the same generic type, *New Orleans, Astoria, Minneapolis, Tuscaloosa,* and *San Francisco,* are under construction, and a sixth is to be begun this year. The aircraft carrier *Ranger,* building at Newport News, will shortly be launched. She displaces 13,800 tons, will be armed with eight 5-inch guns, and is to carry over seventy aircraft. No other details of this ship are available. Eight destroyers were begun during the year, the first batch to be ordered since the war-time programs. They are craft of 1500 tons and will cost 4,700,000 dollars each (£940,000 at par). Three new fleet submarines were begun in 1930–31, the *Dolphin, Cachelot,* and *Cuttlefish.* They are of uniform design; 1560 tons displacement, surface speed 18 knots, armed with a 4-inch gun and six tubes.

JAPAN.

Possibly as a result of the political situation in the Far East there was little news of Japanese Naval developments in the past year. During the summer the *Chokai,* the eighth and last of the 10,000-ton cruisers allotted to Japan by treaty, was delivered from the Mitsubishi yard. The type was fully described last year, and it need only be repeated that these ships incorporate a higher ratio of armament, protection, and horsepower than any other cruisers of equal tonnage. The aircraft carrier *Ryujo,* of 7600 tons, is nearing completion at Yokohama. She represents an attempt to build a floating aerodrome of moderate tonnage, in contrast to the monster ships up to 33,000 tons, now in service, which are not only very expensive to operate, but are dangerously vulnerable. Two cruisers of a new type were laid down in 1932. They are reported to be of 8500 tons and 33 knots speed, and will be armed with fifteen 5.1-inch guns. This, curiously enough, is the same armament as that of the Russian cruisers of the *Profintern* class, which were designed before the war. The last destroyers of the *Fubuki* class (twenty-four units) were launched during the year. Displacing 1700 tons, with a contract speed of 35 knots, and mounting six 5.1-inch guns and nine 21-inch torpedo tubes, they are, in proportion to their size, the most heavily armed destroyers afloat. Five boats of modified design have been laid down, together wth two 600-ton torpedo boats, of which no details are known. A reduction has also been made in submarine dimensions, the three boats started during the year being of 1300 tons, as compared with 1638 tons in the preceding class. The following ships are projected and may be laid down in 1933:—Two cruisers of 8400 tons, three destroyers, three submarines, a mine-layer of 5000 tons, three smaller mine-layers, two torpedo boats, five mine-sweepers.

FRANCE.

As noted in the introduction, the battle-cruiser *Dunkerque* has apparently been laid down at Brest, though the reports to this effect may refer to preliminary work rather than to the actual laying of the keel. In any case, however, the ship is assured of early construction. Although described officially as a counterweight to the German miniature battleships of the *Deutschland* class (10,000 tons, 26 knots, six 11-inch guns), the *Dunkerque's*

design indicates that a much broader view of her functions has been taken. After repeated modification the plans now provide for a ship of 26,500 tons, with a speed of 30 knots, and a main armament of eight 13-inch guns in quadruple turrets, one forward and one aft. This novel method of mounting the guns has been adopted to save weight and concentrate protection. The four weapons in each turrent are in two groups, divided by a bulkhead. Special attention has been given to the lay-out of the magazines, each of which has a capacity of nearly four hundred rounds of 13-inch shell. To avoid bringing the shell and powder spaces too near the sides of the ship, where they would be liable to be affected by torpedo explosion, they are laid out logitudinally. The armor and underwater protection of the ship has been carefully studied, and it is predicted that the *Dunkerque* will be equal in fighting power to any battle-cruiser now in existence with the sole exception of H.M.S. *Hood*. She is to be completed towards the end of 1935. Following the launch on May 21st, 1932, of the *Algérie*, her seventh cruiser of the 10,000-ton class, France has reverted to smaller dimensions, and the new ships now on the stocks, *La Galissonnière* and *Jean-de-Vienne*, displace only 7729 tons. The speed is to be 31 knots and the armament, nine 6.1-inch guns in triple turrets, corresponding to that of the German 6000-ton ships of the "K" and "Leipzig" class. Four additional cruisers of the same type are to be laid down in 1933. A powerful cruiser-minelayer, the *Emile Bertin*, is in hand at the Penhoët yard, St. Nazaire. She is 548 feet in length, with a displacement of 5886 tons, and a contract speed of 34 knots. Her armament is nine 6.1-inch guns on triple mountings and she will carry several hundred mines.

All the flotilla leaders of the 1929 program are now afloat. These formidable craft, which are really light cruisers, are purely French in conception, and no less than thirty-one have been built or ordered up to the present. The latest displace 2500 tons and are engined for 37 knots, the armament comprising five 5.5-inch guns, five smaller pieces, and nine 21.7-inch torpedo tubes. Several of the type have achieved phenomenal speeds on trial. The fastest to date is the *Cassard*, with a maximum of 43.4 knots and a mean of 42.9 on a three-hour run, the displacement being 2646 tons. This vessel was built at the Chantiers de Bretagne at Nantes, and is fitted with Rateau turbines. The *Gerfaut* has attained 42.3 knots and the *Tartu* 41.2, the latter having to her credit an average of 38.58 knots for eight hours on a displacement of 2700 tons. These remarkable performances reflect high credit on the designers, constructors, machinery contractors, and engineering staff of the vessels in question. The latest official returns show that France has 109 submarines built, building, and authorized. The various types composing this impressive flotilla have been described in "The Engineer" from time to time, and there have been no new developments in the past year. During the autumn a 5000-mile voyage to West Africa and back was made by the submarine-cruiser *Surcouf*, without hitch of any kind. This vessel, the largest submersible in the world, is nearly 400 feet in length, has a surface displacement of 2880 tons and a maximum speed of 19 knots. She is the only underwater craft to be armed with 8-inch guns, of which two are mounted.

A novel type of convoy sloop, or *escorteur*, has been developed, four of which are building and eight projected. They are ships of 600 tons, the speed is said to be high, and they mount four 3.5-inch guns and several depth-charge throwers. The first group of "colonial" sloops was completed during the year. Displacing just under 2000 tons, they are oil-engined for a speed of 15½ knots, and are credited with an endurance of 9000 miles at economical speed. They are armed with three 5.5-inch and several smaller

guns, and are also equipped for laying mines. There will eventually be seven of these vessels, representing a type which might prove very useful to the British Navy, especially for convoy work and in view of the shortage of cruisers. They possess the further advantage of being exempt from treaty restriction.

ITALY.

It is reported from Rome that plans for a capital ship have been prepared and various models tested in the experimental tank at Spezia, the inference being that a "reply" to the French *Dunkerque* is in contemplation. The *Bolzano,* which went afloat in September, is the seventh and last cruiser of the 10,000-ton class. Unlike the four preceding ships, in which the speed was reduced to 32 knots to secure better protection, the *Bolzano* has been designed for 35.5 knots. Presumably, therefore, her defensive armor is very light. All six ships of the *Condottieri* class—5080–5090 tons, 37 knots, eight 6-inch guns—are now afloat, comprising a homogeneous squadron of unprecedented speed. On her trials the *Alberico di Barbiano* of this class touched 42.1 knots, the *Alberto di Giussano* reached 40.7, and others have approached 40 knots. An improved type of cruiser has since been developed, displacing 6700 tons with a contract speed of 38 knots—the highest yet recorded. Four of these ships were begun in 1931-32, and two more are due to be laid down in January or February, 1933. It is worthy of note that both France and Italy have made provision for nineteen cruising ships since the war, but while the French total includes a training ship (*Jeanne d'Arc*) and two mine-layers (*Pluton* and *Emile Bertin*), all the Italian vessels are "straight" cruisers. The latest Italian destroyers are medium craft of 1225–1472 tons, and 38 knots, with a uniform armament of four 4.7-inch guns and six to eight torpedo tubes. The single large funnel gives them an unusual appearance, but the housing of all boiler uptakes in one casing is an innovation which has many advantages and seems likely to be widely copied. In November, 1932, Italy had forty-six submarines completed and twenty-nine under construction, the latter ranging from ocean-going craft of 1390 tons to coastal boats of 636 tons.

OTHER NAVIES.

Germany's first "pocket battleship," *Deutschland,* is due for delivery before the end of this year. The second, *Ersatz Lothringen,* was begun at Kiel in June, 1931, and the third, *Ersatz Braunschweig,* on October 1st, 1932. These ships, together with the new cruiser *Leipzig,* were fully described in last year's review. The small cruiser, or artillery tender, *Bremse,* was completed during the year. A ship of 1250 tons, she is chiefly remarkable as being the fastest oil-engined warship which has yet been built. Her machinery, described in last year's review, develops 25,000 B.H.P. and drives her at 27 knots. Her trials are reported as having been satisfactory.

A new cruiser of approximately 6000 tons, with a 6-inch armament, is under construction for the Netherlands Navy at the Wilton-Fijenoord yard, Rotterdam. She is to be fitted with the latest type of Yarrow high-pressure water-tube boiler, and Messrs. Yarrow have received the order for the complete working drawings for these generators.

The Swedish "aircraft-cruiser" *Gotland,* the first of her type to be built in any country, will be launched during the year. Particulars: Length on waterline, 426½ feet; beam, 47¾ feet; displacement, 5260 tons; designed S.H.P., 33,000=27 knots. She will mount six 6-inch guns in two double and two single turrets, four light A.A. pieces, and six deck torpedo tubes. The

after part of the ship is reserved for aircraft, stowage being provided for at least a dozen seaplanes, with a catapult for starting them on flight. The design of this vessell has been worked out with the utmost care, and her performance at sea will be watched with keen interest. The flotilla leader, *Dubrovnik*, designed and constructed by Yarrow and Co., Ltd., was handed over to the Royal Yugoslav Navy on May 14th. She has a length of 371 feet, and was described in our issue of June 17th. An interesting feature of the trials was the taking of aerial photographs at 37 knots.

A grievous loss was sustained by the Spanish Navy in August, when the cruiser *Blas de Lezo* (closely resembling the British "D" class) was wrecked off Cape Finisterre. The only notable ship to go afloat was the 10,000-ton cruiser *Baleares*, at Ferrol in April. In general design she resembles the British "County" class, but the uptakes are trunked into a single funnel, the horsepower is increased to 90,000 and the speed to 33 knots. The plans and much of the material are of British origin.

During December it was announced that the Portuguese Government had decided to place the following Naval contracts with British firms:—Two first-class sloops with Hawthorn, Leslie and Co., Ltd., Hebburn-on-Tyne; three submarines with Vickers, Ltd., Barrow; one destroyer with Yarrow and Co., Ltd., Scotstoun. These orders, secured in the face of strong foreign competition, complete the entire Portuguese Naval program, several of the earlier units of which are also being constructed in British yards.—"The Engineer," Jan. 6, 1933.

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(Special problems of corrosion-resisting steel castings.)

4. W. C. HANAWALT—Foundry Factors in Design of Steel Castings—Jour. Westn. Sec. Engrs., Vol. 37, No. 2, Apr. 1932, page 82.

5. C. E. SIMS—Design of Steel Castings—Octagon, Vol. 35, June 1931, page 6.

6. E. VEIBE, JR.—When Designing Steel Castings Products—Engineering, Vol. 2, Aug. 1931, page 352.

7. F. MELMOTH—Steel Foundry Complexities—Heat Treating and Forging, Vol. 16, Aug. 1930, page 1006, 1014.
(General discussion of steel founding problems, with some hints on design, by an acknowledged expert.)

8. D. G. ANDERSON—Casting Design Yields Savings—Iron Age 1929, Vol. 123, Mar. 1928, page 868.
(Concrete examples of savings produced by attention to design. About 4 pages.)

9. D. M. AVERY—How Castings Meet Designers' Needs in Modern Machinery—Machine Design, Vol. 1, Sept, 1929, page 26.
(General discussion covering iron and nonferrous as well as steel castings.)

10. R. A. BULL—Steel Castings as Machine Parts—Design, Vol. 3, No. 4, Apr. 1931, page 36.
(A few hints on design by an expert, 3 pages.)

11. H. R. BARTELL—Design and Manufacture of Special Steel Castings for Rolling Stock—Canadian Foundryman, Vol. 22, Feb. 1931, page 18.

12. F. C. EDWARDS—Design and Shrinkage—Foundry Trade Journal 1928, Vol. 39, Aug. 2, page 75.
(British viewpoint, 1 page.)

13. J. H. HALL—Defects in Steel Castings and the Remedies for Them—Trans. Am. Foundrymen's Assn., Vol. 23, page 537.
(Same material given in author's textbook, see below.)

14. C. W. BRIGGS and R. A. CAZELIUS—Detecting Defects by Radiography, Using Gamma Rays—Trans. Am. Foundrymen's Assn., July 1931, page 65.
(Methods of non-destructive examination.)

15. J. E. FLETCHER—Steel Casting Design and Manufacture—Foundry Trade Journal, Vol. 20, page 295, 375 (1918).
(14 years old. The author's ideas have not found wide acceptance.)

16. C. F. PRESTON—Practical Notes on the Design and Treatment of Steel Castings—Chem. Met. Eng., Vol. 23, page 529 (1920).
(Small notes and hints.)

17. A resume of Published Data on Steel Foundry Practice. Ohio State University Studies, Engineering Circular No. 25. The Ohio State University, Columbus, Ohio, 1931.
(A good bibliography of published material on factors affecting the surface of steel castings.)

18. The Steel Foundry, by John Howe Hall. McGraw-Hill Book Company, New York, 1922.
(Standard Text Book. Not much information on design.)

ASSOCIATION NOTES.

ELECTION OF OFFICERS FOR 1933.

The following have been elected officers of the Society for 1933:

President:

Rear Admiral William A. Moffett, U. S. N.

Secretary-Treasurer:

Commander H. B. Hird, U. S. N.

Members of Council:

Captain R. C. Davis, U. S. N.
Captain C. A. Bonvillian, U. S. N.
Captain Henry Williams (C. C.), U. S. N.
Captain Jno. Q. Walton, U. S. C. G.
Commander C. A. Jones, U. S. N.
Mr. J. H. King.
Mr. C. P. Wetherbee.

BANQUET.

Because of the general economic conditions, the loss of pay already sustained by Naval members and the uncertainty occasioned by pending legislation, it has been very reluctantly decided not to hold the usual banquet of the Society this year.

MEMBERSHIP.

The following members have joined the Society since the publication of the last preceding JOURNAL:

CIVIL.

Hersey, Mayo D., Evergreen Hall, Woodbury, N. J.
Livingston, John, Room 3401, 170 Pine St., New York, N. Y.
Locke, John H., General Steel Castings Co., Eddystone, Pa.
Noyes, Mason S., 2327 Navy Department, Washington, D. C.

ASSOCIATE.

Alexander, John, Barclay Curle & Co., Glasgow, Scotland.
Meyler, George, 2115 Washington Ave., New York, N. Y.
Winsor, Thomas W., 1427 Gregory Way, Bremerton, Wash.